THE UNIVERSITY OF ALBERTA

NATURE IN THE URBAN LANDSCAPE: A REVIEW AND BIBLIOGRAPHY OF URBAN ECOLOGY

by

© PENELOPE ANN BONNETT

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Nature in the Urban Landscape: A Review and Bibliography of Urban Ecology" submitted by Penelope Ann Bonnett in partial fulfilment of the requirements for the degree of Master of Arts.

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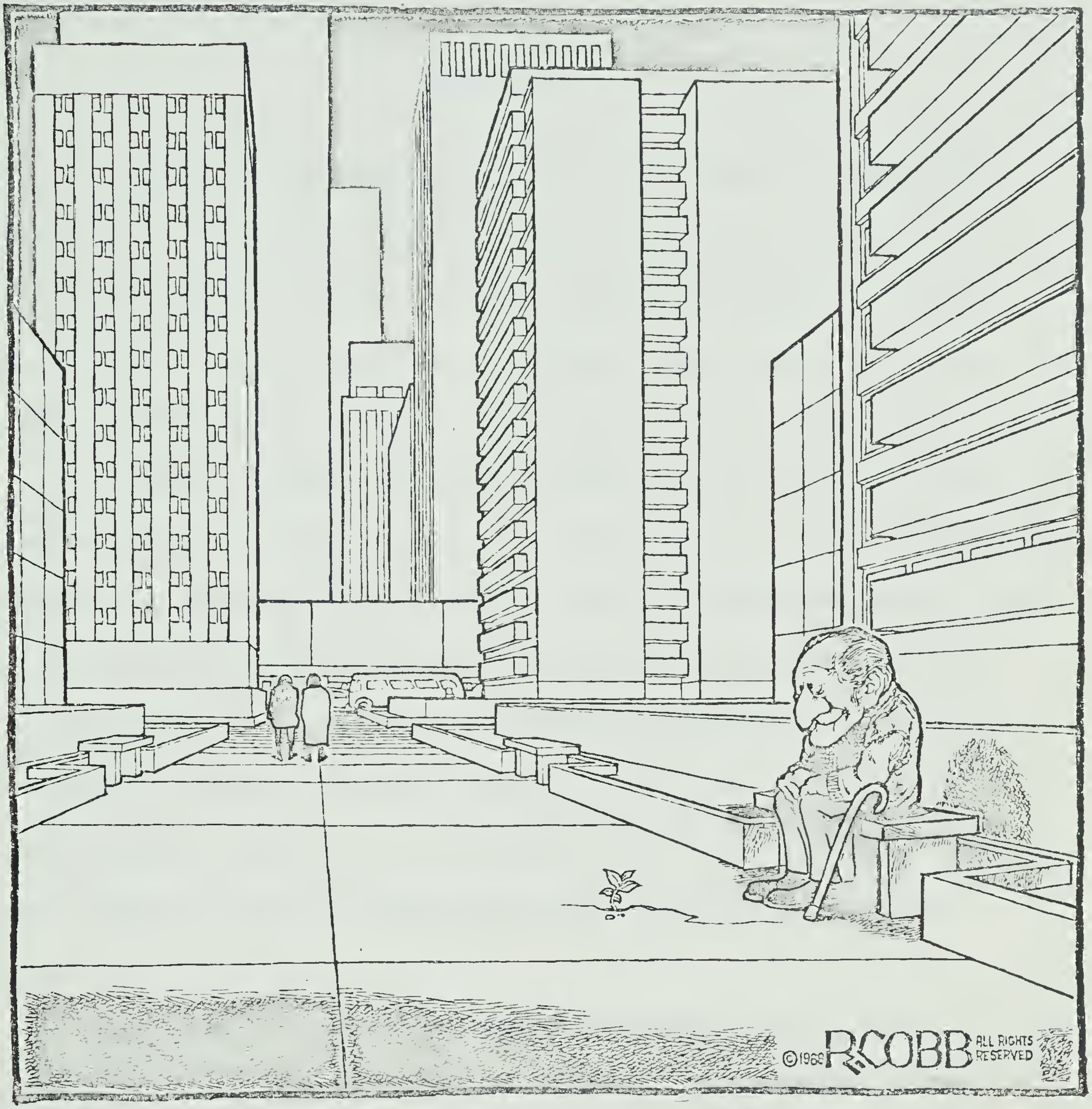
"The city, for all its congestion, for all its soot and smoke, is not a barrier that can stop the stream of life. It may slow down the movement of the stream, may even reduce it to a trickle but life remains and those of us with eyes to see can seek out and find its myriad branches almost wherever we chance to look."

John Rublowsky,
Nature in the City, 1967



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ABSTRACT

In this study an attempt has been made to assemble information relating to the non-human organisms resident in urban environments. Their special characteristics, if any, their adaptations and ability to exploit the urban environment are considered together with the biotic interactions.

In order to more clearly understand some of the factors that permit nature to form an integral part of the urban landscape the metropolis of London has been scrutinised. The basic determinant is the climate which sets limits upon the number and type of organisms potentially capable of existing in the area. It is obvious, however, that the morphology of the open space network is a critical factor in the maintenance of viable wildlife populations in densely populated regions.

The possibility of enhancing nature in the city is considered with respect to three topics. The present and future land-use planning practices, knowledge of habitat creation and management and the problems associated with the presence of people and wildlife in close proximity.

Examples are provided of schemes for "planned nature" in urban areas and also some guidelines for urban open space managers. Finally, a summary of the principal findings

arising from this survey is accompanied by recommended areas for further research.

A bibliography containing some four hundred references which pertain to the wide-flung subject of urban wildlife ecology is appended.

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CHAPTER I

INTRODUCTION, RATIONALE AND PROCEDURES

1.1. Introduction

Urban ecology is an important part of human geography but rarely have the non-human organisms in the urban ecosystem formed the focus of study. Nature in the urban landscape is an underrated resource whose aesthetic, educational and functional values have yet to be thoroughly understood.

The city is primarily the habitat of man but it is also utilised by a surprising array of other species, the majority of which go unnoticed by the urban populace.

Little research has been conducted to investigate the interactions of man and his wild neighbours in the urban ecosystem and the influence of the built environment on all living material.

In 1945, Fitter wrote the first book on urban ecology when he gathered together a history of the growth of London and its effects upon the indigenous flora and fauna. In a similar vein Kieran (1959) considered the natural history of New York City and described the amazing resilience of many species in the altered environment. It would appear that few other cities have been subjected to such scrutiny and we

therefore have little knowledge of the limiting factors exercised upon natural populations in the man-made environment.

The objective of this study is to draw attention to the available information on urban flora and fauna with a view to assisting resource managers who may wish to enhance the natural elements in their cityscape.

The likelihood of an increase in the amount of green space incorporated in urban developments is considered in Chapter IV. In the event that this increase is realised there will be an excellent opportunity for planners and wildlife managers to cooperate in the development of stable, natural communities as an integral part of the human habitat. This may be expected to markedly enhance the quality of the urban environment whilst at the same time performing a functional role in the regional ecosystem.

1.2. Rationale

This study was motivated by a commitment to the idea that environmental quality can only be maintained or restored when a well-informed and ecologically-oriented public applies pressure to its elected representatives (Brandwein, 1966).

A considerable volume of literature in the past ten years has focussed on the need to alter the methods of evaluating civilisation's progress if mankind is to survive without further accelerating the rate of biospheric contamination (Commoner, 1963; Boulding, 1966; Caldwell, 1966; Arvill, 1967;

Galbraith, 1967; Dasmann, 1968; Howard, 1969; Platt, 1969; Slatyer, 1970; Spilhaus, 1971). With the rise of affluence and the increasing amount of discretionary time available to urban dwellers there is a growing awareness of the need to maintain beauty in our everyday surroundings. Although quality of the environment has become a concern of many different groups in society, if the growth ethic is to be replaced by a desire to maintain a stable, self renewing system there is a need for each person to have the opportunity to enjoy direct communication with natural phenomena on an everyday basis. As Weinberg (1970) observed, we should eradicate the idea of preserving National Parks because this has led us to the point where we live in squalor most of our lives and enjoy beauty and nature only by travelling to these "holy shrines".

In view of the projected continuation of urbanisation and urban growth it is vital to consider the implications of the ever-widening gulf over which the average man interacts with nature especially in terms of his essential life requirements. A fundamental question deserving thorough investigation concerns the ability of those whose entire early experience is gained in the built environment to comprehend the intricacy of the ecosystem to which they belong. The quality of life in the future is in the hands of an urban-based populace. It is the city people who will elect representatives who will in turn make the vital decisions which can so drastically affect natural resources.

It is the author's contention that environmental education, employing ecological principles to establish a framework within which all studies can be taught, provides the main hope for a change in society values. If such an innovation is desirable, it is apparent that for many schools the resources with which to demonstrate ecological concepts are not readily accessible. It seems therefore that greater attention should be paid to enhancing and creating "natural" habitats in population centres.

This study is therefore based upon the assumption that it is desirable to enhance natural communities in the urban environment. It attempts to draw together material from diverse subject areas and should be regarded as a preliminary step in what it is hoped will be a continuing project. A review of the more important aspects of urban ecology is presented together with a bibliography of information relative to this subject.

Several questions were posed at the outset to clarify the basic issues involved in the concept of "planned nature":

1. Is it possible to maintain viable, natural communities in cities?

2. What values result from the presence of nature in the city?

3. Do urban plants and animals possess special characteristics?

4. What are the principal factors limiting their existence?

5. Which of the existing management techniques are applicable to city vegetation and wildlife?

6. What are the implications of nature in the urban landscape to the planning profession?

7. What further research is necessary to establish the validity of the concept of increasing natural communities?

1.3. Procedures Employed in the Study

As an initial step, a survey was conducted of the various methods of information retrieval, classification, and storage. Computer-tape storage and retrieval on the basis of keywords was investigated but rejected in view of the limited knowledge of the true extent of material to be handled in this study.

The possibility of using a computerised searching service was discarded for two reasons. First, such services are expensive and may be of limited value in a study covering a very wide subject range; the amount of noise to be expected is also great. Secondly, many of the currently available services do not extract the journals in which the most relevant material is located; furthermore no retroactive service was available.

A simple card file system was thus selected to handle the bibliography, based upon the assumption that the search would not reveal an amount of material in excess of the capacity of such a system.

Throughout the research period, manual searching of indexes and abstracts was used, with continual follow-up of all accidentally discovered materials. The greatest shortcoming of the methods employed is in the bias which has been

introduced; there is a leaning toward the strictly biological, non-human aspect of urban ecology and there is a concentration on literature in the English language.

An original intention was the compilation of a fully annotated bibliography but this proved impractical. Many references which were cited in papers could not be consulted directly; these have nevertheless been included so that any user of the bibliography may become aware of them.

To extend the range of information sources beyond the library system, a questionnaire was sent to a number of ecologists and biologists in Europe and America (see Appendix A). Selection of respondents was based on a display of interest in the subject of urban ecology as evidenced by their published work. The response to the questionnaire was very mixed. Some were not acknowledged, others were returned without completion and a plea of ignorance of the topics covered, yet others drew responses which showed interest but no knowledge. A few showed evidence of considerable thought and time expended on the part of the respondent. In general, there was little value in this exercise beyond confirming some of the author's ideas and illustrating the fact that few people have studied urban ecology per se.

Another mode of gathering ideas and evidence was through the medium of personal interviews with people concerned in the practice of wildlife management.* Visits were

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*A list of agencies, personnel interviewed, and correspondents is given in Appendix B.

made to Washington, D.C. to speak with experts in the Fish and Wildlife Division of the United States Department of the Interior, to Chicago for the North American Wildlife Conference, where consultations were held with experts in this field, and to London, England, where members of several conservation organisations were interviewed. Throughout this period follow-up correspondence was conducted with people whose papers had provoked ideas or whose work had been mentioned by others. In this way several valuable pieces of information came to light.

CHAPTER II

THE CITY ECOSYSTEM

2.1. Ecosystems and Biotic Interaction

2.1.1. Ecosystems

An ecosystem may be defined as the basic functional unit of nature; a complex of biotic and physical factors interacting in the boundary layer formed by the atmosphere - lithosphere interface. Bormann and Likens (1969) have visualised the ecosystem as a series of components, for example species populations, organic detritus, available nutrients, atmospheric gases and water, all of which are linked through energy fluxes, geochemical cycles and food webs. Odum (1969:262) provided the following definition

> . . . a unit of biological organisation made up of all the organisms in a given area . . . interacting with the physical environment so that a flow of energy leads to a characteristic trophic structure and material cycles within the system.

The development of such a system through time is influenced by physical phenomena but biotic modification, in the form of increased organisation and homestasis, serves to progress the system. It is known that the existence of a particular species population will bring about changes tending to create new conditions favouring other species typical of more mature phases. A successful population is one which

is able to channel energy efficiently and re-cycle materials such that an increasingly closed system develops allowing resources to be conserved and the species maintained.

Thus the complexity of any particular ecosystem is a function of its developmental stage. Species diversity stabilises the system by increasing the number of routes through which energy may flow, thus the greater the number of species the more stable the system. Complexity serves to control population growth through the use of feedback mechanisms which intensify the amount of interaction between species. Ecosystem complexity has the beneficial effect of curtailing the likelihood that any one species grows explosively and in addition it modifies significantly the potential perturbing influence of external forces (Leigh, 1965; Margalef, 1968; Klopfer, 1969).

2.1.2. Biotic Interaction: Man as a Perturbing Force in the Urban Ecosystem

In the so-called advanced countries man has assumed, in large measure, the role of principal agent for change in the environment. Man-modified systems are distinguished by high energy inputs and turnover rates, lowered species diversity and low stability. The human species in pursuit of maximum yield has diverted energy, water, and other materials from mature natural systems and used them to create his own unstable system. Activities which have important implications for natural communities include removal of vegetation cover

by tilling, logging, or burning; land drainage or inundation; earth moving and extractive processes; introduction of exotic species; pollution of air, water, and soil.

In cities there is evidence of direct human effects upon plants in the existence of multilated street trees, trampled and sometimes eroded open space, manicured ornamental gardens, a lack of both mature trees and leaf litter and a low species diversity. Animals are adversely affected by a great variety of inimical activities, including illegal shooting, poisoning, trapping, damage to nests and young, use of high speed forms of transportation, and removal of old trees and buildings.

Perhaps of greater importance are the consequences of human activities such as housing or industrial development. Habitat destruction is probably the greatest cause of diminishing animal numbers and many plants with highly specialised requirements are excluded from populated regions. The removal of vegetation has far-reaching effects upon the animals which utilise it for an energy source and the general result is a great simplification of the ecosystem. Taken together with the ubiquitous influence of pollution, there is considerable evidence that man changes the carrying capacity of the environment, thereby altering the competitive advantage between species such that some are better able to survive in the new conditions than others. Natural populations in cities can therefore be expected to contain adaptable species typical of the early stages of ecosystem development.

2.1.2.1 Modification of the Abiotic Environment

The cultural evolution of mankind has produced important and readily visible effects upon the natural landscape. In addition, subtle and sometimes unperceived changes have occurred with the advent of technologic man with his increasing ability to insulate himself from the elements and their unwanted influence. The emergence of large population centres with their inherent emphasis upon the artificial, built environment has meant a substantial adjustment in the natural communities which formerly occupied these areas.

Many species have been eliminated while others have managed to exist in peripheral areas only to be driven further away as habitat is destroyed with each new subdivision development. Perhaps of equal importance both to man and other creatures is the alterations which the city structure creates in both the hydrological and energy budgets in its vicinity. Viewed from the standpoint of non-human organisms *Homo sapiens* can be regarded as both a beneficial and a detrimental force acting to change the ecosystem. Associated with the growth of a city are certain processes of alteration:

1. Removal of plant cover and replacement by concrete, asphalt and other rock-like materials of greatly reduced porosity, and increased thermal capacity.

2. Increased rates of surface water run-off, lowering of ground water reserves, and reduction in exposed water surfaces, marsh and other wetlands.

3. Dispersal into both air and water of numerous inorganic and organic compounds and elements which modify the energy balance.

4. Release of heat energy as a result of combustion processes.

The effects of these processes are reflected in the rather specialised character of city climates. Many investigators have documented the measurable differences between the meteorological conditions of the city and its rural environs (Brooks, 1952; Landsberg, 1962; Chandler, 1965; Geiger, 1965; Lowry, 1967; Maunder, 1969).

The principal changes to be expected in the typical city have been summarised by Maunder (1969) and are presented in Table 2.1. It is important, however, to recognise that within any urban area there are a series of micro-climates which result from local topographic and other controls such as the types of land-use. For example, Chandler (1965) in his study of London demonstrated that open spaces in the central zone displayed marked temperature contrasts when compared with adjacent streets; temperature differences between Hyde Park and nearby residential areas were as great as 2.3°F. Similarly, an abrupt drop of 1.0°F occurred on passing from the street onto Clapham Common. Such temperature gradients are at a minimum around noon and they range, over a twenty-four hour period, from 0.50°F to 2.9°F in the London area. A transect from the outer suburbs through the central district and on across the Thames to the southern periphery revealed the expected differences in temperature resulting from the high thermal capacity of the densely populated areas. Chandler (1970:88) in a recent essay about man's effect upon

Table 2.1.

Climatic Changes Produced by Cities

Element	Comparison with Rural Environs
Contaminants:	
dust particles	10 times more
sulphur dioxide	5 times more
carbon dioxide	10 times more
carbon monoxide	25 times more
Radiation:	
total on horizontal surface	15 to 20% less
ultraviolet, winter	30% less
ultraviolet, summer	5% less
Cloudiness:	
clouds	5 to 10% more
fog, winter	100% more
fog, summer	30% more
Precipitation:	
amounts	5 to 10% more
days with 0.2 in.	10% more
Temperature:	
annual mean	1 to 1.5°F more
winter minima	2 to 3°F more
Relative Humidity:	
annual mean	6% less
winter	2% less
summer	8% less
Wind Speed	
annual mean	20 to 30% less
extreme gusts	10 to 20% less
calms	5 to 20% more

Reproduced from Maunder, 1969 : 25

the climate, emphasised that a

> striking and certainly the most obvious departure from natural conditions is the canopy of solid, liquid and gaseous pollutants which covers many cities, particularly in winter. . . . (and the) high concentration of carbon monoxide and other gases. . . . from car exhausts which can exist for short periods in the bottom of deep urban chasms congested by slow moving traffic.

He also pointed out how airflow is altered by the presence of buildings and their relative positioning (Chandler, 1970: 90).

> The acceleration of winds along streets parallel to the free wind and the development of eddies across streets running at right angles to the wind are well known phenomena aggravated by grid-iron patterns or urban development and high-rise buildings.

These features of the city climate taken in conjunction with lowered humidity, reduced radiation and increased frequency of light rainfall (Table 2.1) have important bearing on the survival of organisms living within the built environment.

A point which should be stressed is that the city is an ecosystem; an intricate web of interacting organisms involving energy transfer and materials cycling. Unfortunately, at the present time many of the cycles remain unclosed resulting in the accumulation of so-called "wastes" which threaten the existence of our civilisation within the foreseeable future (Ayres and Kneese, 1969). Much of the material dispersed into the air is carried by winds to areas remote from the source, quite a large quantity is returned to the city surface by rainfall and gravity. Thus we find acidified

soil in urban areas, elevated levels of heavy metal elements and pesticide residue, and perhaps many as yet unperceived side-effects of our tendency to ignore natural laws (Fahey and Butcher, 1965; Thomas, 1965; Purves, 1966).

2.1.2.2. Effects of Changing Technology on Animals

The house sparrow (*Passer domesticus*) is thought to have reached its peak population during the period of horse drawn transport because of the abundant sources of food and nesting sites. The more widespread use of wood in buildings at that time also resulted in a greater variety of suitable nesting and roosting spaces. By the 1930s with the replacement of the horse by the automobile the sparrow was forced to seek new food sources and a noticeable decline in numbers occurred (Summers-Smith, 1963).

The emergence of a 'clean and unfettered' architectural style over the past thirty years has affected many birds which previously took advantage of the 'cliff' habitat in the city. Bats and owls have also suffered from this change as modern church design rarely includes the kind of bell-towers and spires which formerly provided a significant amount of roosting and nesting habitat.

Utility poles are of functional importance to many birds since they serve as songposts, look-outs for predators, and potential sites for hole-nesting species. The wires strung between the poles and pylons seem to be both beneficial and detrimental to wildlife; lines are used extensively

by fledgling birds and migrants. However, many birds meet their death by causing short-circuits between adjacent power lines, or by flying into them (Harrison, 1963; Benton and Dickinson, 1966).

Modern planning practice requires that utilities be placed underground in new communities and this will reduce essential habitat features for some birds. Attention may then be focussed upon the metal lampstandard which has for long been successfully utilised by the house sparrow.

The reduction in the use of wood as a building material affected not only the sparrow. Several other vertebrates and some insects were affected and excluded from non-wood dwelling places. The house mouse (Mus musculus) is a very adaptable creature however and can be found wherever man settles, particularly in association with food storage. Cold storage rooms have been colonised by mouse populations able to survive in freezing temperatures while exploiting the abundant source of fat and protein (Fitter, 1945; Rublowsky, 1967).

Some forms of advanced technology present problems which are not easily overcome by wildlife species. A fairly recent addition to the urban environment is the tall building or television mast extending far into the sky (some reach heights greater than a quarter of a mile). Such structures possess warning lights to minimise the danger to low-flying aircraft but this unfortunately enhances their danger

to migrating birds. Thousands of migrants may die at one location during each night of the short season when they follow traditional flight routes across continents. The erection of a tall building always causes a huge death toll until the birds learn to avoid the obstacle (Time, 1970, 96[12]:10). In Wisconsin a typical example was the loss of life occasioned on one night by a new mast; 5,595 birds died. In the worst instances as many as 15,000 casualties have been reported when migration activity is intense (Vosburgh, 1966). Experiments with floodlights to illuminate the obstacle have shown that it is possible to reduce such deaths.

A very famous example of adaptation to changing technology through natural selection is the case of the peppered moth (*Biston betularia*) in the industrial areas of Britain. Kettlewell (1958, 1961) has described how the predation pressure on the differently pigmented varieties of this moth changed as a result of heavy particulate pollution. During the nineteenth century intensively industrialised centres such as Manchester and Birmingham experienced loss of their lichen flora and the trees became coated with soot. The originally well camouflaged pale variety of the moth was placed at a disadvantage and fell prey to insectivorous birds. The dark form thus held the competitive advantage and it has since become very common. This case of industrial melanism was the first in which natural selection had actually been observed in the field and emphasised the relatively short period over which such changes can occur. It is now known that

many species of moths exhibit melanism, particularly those which rest on tree trunks when not in flight (Lond. Nat., 1966, 45:91).

The wealth of new materials now used by man has produced a concomitant change in the type of nesting materials available to birds. Species which frequent populated areas utilise a variety of objects including cellophane paper, toffee wrappers, lemonade straws, steelwire cuttings, plastic covered cable and plastic sheets (Lond. Bird Rep., 1963, 26:73). An entertaining account of an innovative moorhen (*Gallinula chloropus*) suggests that new materials may also be used for purposes other than nest construction. Hawkins (1970) reported seeing a brooding hen using a piece of polythene sheet as a protection against rain showers.

The scarcity of open water in cities has caused reptiles and amphibians to be largely extirpated. The drying up of pools due to drainage during development results in loss of breeding grounds for common frogs (*Rana temporaria*) and toads (*Bufo bufo*). Woollacott (1961-7) believes that this reduction in habitat causes a great increase in inter-specific competition a common form of which is egg eating, and that this further explains the scarcity of these animals in urban areas.

Other organisms have shown themselves more adaptable and the many sources of heated water in city areas has proved an attractive habitat for many aquatic species. In London

it is reported that some species of tropical fish are found breeding near power station outfalls (Lond. Nat., 1969, 48: 85).

No doubt there are other instances where technological advances have been exploited successfully by plants and animals, but many species are adversely affected. Until the 1940s the rate of advancement was such that many organisms could adapt and maintain viable populations, but the rapidity and extensiveness of new technical developments since the war may have been too great to allow adaptation. Indeed it is possible to forecast a decrease in city wildlife populations if no positive action is taken to maintain their habitat.

2.1.3. Biotic Interaction: Effects of Plants and Animals Upon Man

2.1.3.1. Health Hazard

The air contains numerous viable particles which may cause disease or allergic reation in susceptible people. Ragweed pollen is known to cause great misery to countless individuals each year. An average plant is capable of dispensing several million pollen grains each day of which some are carried in air currents and widely disseminated (Harrington and Metzger, 1963; Jacobson, 1968). Bacteria, fungal spores, and insects are the other important components having detrimental effects upon humans. It is interesting that urban green spaces, although acting as potential sources of pollen

and fungal spores, are measurably less contaminated with bacterial pathogens. In New York City bacteria counts in the air gave values of 3-30 bacteria/ft^3 and the lowest values were found in Central Park where on average the number was only one-third of that found in street air (Jacobson, 1968).

Many birds and animals are potential carriers of disease and could therefore pose a threat to public health if wildlife was encouraged to live in the city. Virulent strains of fungal infections have been detected in dried and weathered pigeon manure taken from old nesting and roosting sites, as well as from fresh droppings and soil in Washington D.C. park. Starling (Sturnus vulgaris) roosts are suspected of being reservoirs of fungal spores capable of causing pulmonary infection (Jacobson, 1968). Some workers are of the opinion that feral pigeons (Columba livia) living in cities represent a distinct health hazard because they can provide a reservoir of ornithosis virus. However, little direct evidence exists that humans have contracted disease from such sources (Lepine and Sautter, 1951; Hughes, 1957; Meyer, 1959; Thearle, 1968).

All warm-blooded animals are potential rabies carriers and at a time of epidemic all the large mammals living in a densely populated area could be considered possible vectors. Animals which might represent such a hazard in cities include opossums, bats, skunks, foxes, dogs, cats and rabbits.

Fur and feather fragments are common allergens hence

urban wildlife populations may be inimical to many people. Another danger inherent in maintaining nature in urban areas is the increased likelihood of aircraft loss due to bird-strikes. If birds congregate in and around airports they can be a hazard to planes although there have been only two instances in the United States where civilian lives have been lost due to this cause. Costly damage to planes has been widespread, however, particularly since the advent of jet engines. Considerable work has been conducted to understand the ecology of these locations and several management techniques have been devised to minimise the attractiveness of runways as feeding and roosting habitat. Other forms of control have aimed at removing the birds by frightening them away prior to the runways being used (Munro and Harris, 1963; Drury, 1966; Solman, 1966; Wright, 1967; Czaja, 1968; Murton and Wright, 1968).

2.1.3.2. Property Damage

Costs incurred as a result of birds using buildings for both nesting and roosting, include the aesthetic and the mechanical damage occasioned by the deposits of excreta on masonry and pavements. The magnitude of such costs in any given place will depend upon the type and numbers of birds involved. Utility companies are believed to suffer considerable losses from the activities of birds which excavate nest-holes in posts and cause breakdowns through the creation of short-circuits between power-carrying lines (Turcek, 1960;

Vosburgh, 1966). Rumsey (1970) has recorded the preference displayed by the red-headed (Melanerpes erythrocephalus) and pileated (Dryocopus pileatus) woodpeckers for freshly creosoted poles in which to nest.

Mammal species can damage growing crops in gardens and parks, as for example the grey squirrel (Sciurus carolinensis) which is prone to strip the bark from trees at certain times of the year (Shorten, 1962). Suburban foxes (Vulpes vulpes) are unpopular with maintenance staff of golf courses in England because of their fondness for playing in sand bunkers. These animals have also been reported carrying away golf balls much to the annoyance of players (Vesey-Fitzgerald, 1965; Teagle, 1967). Another habit of foxes which is perhaps better considered as a nuisance rather than a threat to property is their habit of visiting suburban homes to inspect garbage bins which they regularly knock over.

Plants may also damage buildings when the growth habit of a given species is not appreciated by the property owner. On clay soils roots of willow (Salix sp.) or poplar (Populus sp.) close to buildings can withdraw water to the extent that soil shrinkage results in damage to foundations (Min. H.L.G., 1958; Salter, 1960; Zion, 1968; Jaffa, 1970). Considerable nuisance is caused by herbaceous species forcing their way through asphalt and concrete surfaces on roads, tennis courts and paved walks. Elm trees (Ulmus sp.) are well known for their lack of stability once they become

mature and have been known to demolish homes during gales.

Simpler plants such as fungi or the unique organisms known as slime-moulds may often hasten the demise of old buildings which maintain damp surfaces and thus provide ideal conditions for their culture (Ing, 1964).

2.2. The Influence of the Modified Environment

2.2.1. Known and Potential Effects of the Urban Physical Environment on Plants

In order that it may grow and reproduce, a green plant requires solar energy, atmospheric carbon dioxide, and water, in addition to a variety of elements and compounds contained in the soil. Furthermore, it is important to appreciate that the layer of the atmosphere in which most vegetation grows (the first five feet above the surface) differs greatly from the air mass which extends above. Within this lower layer there is environmental differentiation of surprising magnitude (Geiger, 1965). To a large extent the nature of the plant cover determines microclimatic conditions (within basic topographic controls) and it is therefore possible to have a variety of microclimates within short distances if the vegetation cover forms a heterogeneous mosaic.

For these reasons it is difficult to individually evaluate the numerous climatic modifications resulting from man's activities with respect to plant growth and the food chain it supports. Energy flows and material cycles are intimately related through the living components of the urban

system. For the sake of clarity, an arbitrary separation will be made in order to consider both the known and probable effects of the urban climate.

2.2.1.1. Radiation

Of the several climatic conditions altered by the city environment the one with the greatest potential importance for plant growth is that of reduced radiation received by plant surfaces. There is little information on this topic and considering that this is the basic energy source for the food chain it is important that studies of urban plant productivity be initiated. It can be presumed that the rate of photosynthesis will be reduced but the magnitude will depend upon several other factors. Reduction in radiation results primarily from the dust haze which hangs above the city for the majority of the year. Particulate content in the air is important because a proportion of it is deposited upon foliage and thus further reduces the radiation receipt of the photosynthesising tissues. Annual dustfall in cities is around 1/4 lb/yd^2 and can reach 2 lb/yd^2 in heavily industrialised areas (Mellanby, 1967).

An interesting question worthy of study is the effect of artificial lighting upon plants growing in streets and gardens. Perhaps an attempt could be made to see if photosynthesis is possible during this extended light period and to what degree this increases productivity.

2.2.1.2. Temperature

One consequence of the elevated temperatures to be found in the urban environment is the lengthening of the growing season for plants, and the potential increase can be as great as five weeks in some city areas (Landsberg, 1956). However, it is questionable whether such an extension is beneficial, given the increased air pollution from domestic sources at these periods. An actively growing plant is likely to be more affected by pollution than a quiescent one and thus plants may suffer proportionately more damage at the limits of the growing season in cities. This is one factor contributing to the observed susceptibility of many evergreen species to atmospheric contaminants in towns (Air Pollution, 1969).

2.2.1.3. Humidity

Reduced humidity is most likely to affect the simple plants whose ability to resist desiccation is limited, e.g. lichens and mosses. Lichens are commonly found in "pioneer" situations colonising rocky surfaces in most regions of the world. This ability to survive in barren habitats comes from possession of mechanisms which allow them to efficiently absorb and concentrate nutrients. In addition, they have evolved slow rates of growth so as not to outstrip their available nutrient supply and also possess the ability to store food at times when it is readily produced. Kershaw (1963) states that lichens have been known to survive 56 weeks

of drought without damage. Due to humidity conditions these organisms tend to be at their most active in autumn and spring and in the city this is also a time when air pollution is quite high. Lichens take up water all over the thallus both as a liquid and a vapour.

The study of urban lichens originally reported by Rydzak (1958) suggested that dry air was the primary factor limiting growth of these plants. Shortly after this, however, several researchers in different European cities looked at the question and decided that air pollution (high sulphur dioxide concentrations in particular) appeared to have effects upon the distribution and viability of lichens (see 2.2.3.1).

Following an intensive study of pollution and lichen growth in the New York region, Brodo (1966) decided that humidity did play some controlling part but it was unlikely to be important in cities where sulphur pollution reached measurable levels. He cited studies which had demonstrated the deleterious effects resulting from alternating wet and dry periods and suggested that in addition to air pollution, lichen growth in urban centres may be impoverished for this reason. Against this must be set the statement by Kershaw (1963) indicating the ability of lichens to withstand prolonged desiccation. Microclimatic measurements have revealed that the average moisture content of the air diminishes rapidly with height above the surface (Geiger, 1965) and Skye (1968) working in Stockholm noted the restriction of

many lichen specimens to the lower portions of tree trunks as the central city was approached. It thus appears that for simple plants lowered humidity may be important but its effects are commonly masked by the more drastic influence of pollutants in the urban atmosphere.

One factor contributing to lowered moisture in the city is the paucity of evaporating surfaces due to the lack of vegetation. It is probable that during certain periods, many urban trees are subjected to considerable stress because of the high transpiration rates induced by turbulence, lowered humidity, and higher temperatures, in addition to low soil-moisture levels. The vapour pressure gradient is probably higher than that commonly found in rural areas and it would be interesting to study this aspect or urban tree physiology.

2.2.1.4. Precipitation

Interdependence of the factors which influence growth is further underlined when the effects of increased amount and frequency of rainfall in urban areas are considered. Precipitation has the effect of "washing" the atmosphere and carrying much of the soluble gas and particulate matter down to the various exposed surfaces and ultimately to the soil and waterways. This has produced low pH values in urban soils and at times acidic rain may be damaging to plant tissues in severely polluted areas (Thomas, 1965). Acidification of soils has the effect of making certain key nutrients (Calcium [Ca^{++}] Ammonia [NH_3] and Nitrates [NO_3^-]) less

available than they otherwise would be; in addition, microbial and enzymic activity is restricted leading to further nutrient deprivation of the soil. If the reported effect of increased light showers is generally true in cities, this could have important implications for plant growth. Firstly, it could result in surface rooting due to lack of water penetration and evaporation of water from the surface. Secondly, if the amount of rainfall at any one time is insufficient to wash away completely the accumulations of dust and other contaminants and merely adds further acidic materials, then foliage may benefit little from precipitation. The underside of foliage is less well washed and may suffer excessive build-up of contaminants. Skye (1968) considered acidification of tree trunks in central Stockholm to be a strongly limiting factor in lichen colonisation and growth.

2.2.1.5. Summary

It appears that no systematic study of plant ecology and physiology has been carried out in urban areas. We can nevertheless assume that no single factor will limit productivity, but dependent upon season, type and degree of air pollution, and soil moisture and nutrient availability, reduced radiation reaching the ground may result in decreased photosynthesis. It is interesting to speculate that in some cities such as Paris where measurable increases in carbon dioxide levels have been recorded, (Tebbens, 1968) potential

plant growth rates may be relatively high if water is not a limiting factor. However, the greatest increases occur in the winter and thus are unlikely to markedly influence plant productivity.

2.2.2. Known and Potential Effects of the Urban Physical Environment on Animals

Animals are dependent upon green plants for both an energy source and for cover in their living and reproductive activities. It is thus even more difficult to perceive the direct effects of the modified physical environment.

2.2.2.1. Radiation

Little evidence exists about the effects of reduced radiation on urban animals, but it seems unlikely that this will be of major importance. The extension of daylight hours through the use of artificial lighting does appear to have an influence upon songbird activities. It is reported that English blackbirds (*Turdus merula*) sing at night in central London and have been found nesting during the winter in Berlin (Grummt, 1962; Mitchell, 1967; Blackett, 1970). Both of these occurrences were attributed to the effects of street and display lighting which provide high intensity illumination through much of the night in many cities. Presumably extended "daylight" can provide the requisite stimulus to initiate physiological changes culminating in earlier gonadal activity. In support of this is European evidence that suburban blackbirds breed at least ten to fourteen days earlier

than their rural relatives (Snow, 1958; Havlin, 1963). There have been several reports of blackbirds in central London singing as early as January and as late as August which suggests a greatly extended breeding season for these urban individuals (Lack, 1944; Lloyd, 1944; MacAllister, 1944; Mitchell, 1967). Wood pigeons (Columba palumbus) may nest four weeks earlier in city locations than they do in woodland (Cramp, 1968), and robins (Erithacus rubecula) show a similar tendency (Lack, 1965).

2.2.2.2. Temperature

Increased temperatures are likely to have an important influence on animal activities in urban areas. It is probable that the observations on songbirds reported above are also a function of increased temperature which together with longer days provides the adequate stimulus.

The greatest effect can be expected to occur in the winter when the minimum temperatures are noticeably higher in the city. Birds particularly benefit from the enhanced temperature which reduces the possibility of winter mortality brought about by lack of food and cold stress (Lond. Bird Rep., 1963, 27:5; Snow, 1967). The sight of city pigeons huddled over a street grating on a chilly morning is evidence of the birds' need for warmth and their adaptability to the built environment. There is little documented information on this topic but it may be assumed that small mammals are

able to remain active for longer periods and waterfowl can use city waters as feeding and roosting areas due to the presence of open water (Hochbaum, 1965).

2.2.2.3. Humidity and Precipitation

The reduction in humidity will have little import for mammals but it will determine the distribution of many invertebrates requiring moist conditions for survival. Creatures such as earthworms, slugs, centipedes, wood-lice, etc., may have a very limited choice of living sites in the inner city, but the suburban mosaic of backyards, gardens, parks and school grounds provides a multitude of suitable habitats (Barnes and Weil, 1944, 1945). Many insects have early life stages requiring water and thus in densely populated areas may find such a commodity in scarce supply. In considering the lower animals it may be important to note that the increased run-off and lack of quick absorption in urban areas can often lead to temporary flooding. Such conditions may prove inimical to soil-living fauna as evidenced by the abundance of earthworms to be seen, following heavy rain, crawling on sidewalks and paths.

The reduced vegetation cover together with lower humidity makes life difficult for birds which exist by digging for soil fauna. Snow (1958) from England reported heavy nestling mortality in June among blackbirds due to the dryness and compaction of lawns and flowerbeds in which earthworms reside.

The problem of "acid" rain has been mentioned and the effects upon urban soils may be such as to reduce the faunal diversity, and thus the potential biological productivity of the soil. For instance it is known that different species of earthworm have definite pH preferences and few species can be found in soils whose pH is lower than 4.0 (Satchell, 1967).

2.2.3. Pollution in Urban Areas and Its Effect Upon Living Matter

The effects of man's activities which give rise to pollution are so widespread and important both for man and the other organisms living in his built environment that they demand separate treatment. It is not always easy, however, to distinguish the effects of changes in the physical environment of the city from those caused by ambient pollution.

A city which has evolved over several centuries contains within its boundaries a mixture of land uses with industry located throughout the urban fabric, although it is particularly aligned along transportation routes. Residential property is the other main emission source besides industry and it is clear that stationary sources are ubiquitous throughout the built-up area. Today it is estimated that some 50-60 per cent of all air pollution stems from mobile sources such as gasoline powered automobiles which have access to most of the built environment (Ayres and Kneese, 1969).

The resultant effects upon living organisms are

multiple and research is being conducted in many countries in an attempt to understand some of the interactions which occur (Darley and Middleton, 1966; Katz, 1967; Brandt and Heck, 1968; Stokinger and Coffin, 1968).

Not all cities are equally affected by the various forms of pollution since the intensity of effect is a function of geographical location, population size, types of fuel burned, and nature of industry, in addition to local topography and climate. For example, the air pollution problems experienced in Los Angeles are partially the consequence of high intensity radiation and the location of the city on the coastline hemmed in by mountains. Photochemical oxidation of emitted substances produces secondary products whose toxicity considerably exceeds that of the original compounds, e.g. peroxyacetyl nitrates (PAN) and ozone. As some indication of the automobile as a source of pollutants, reference should be made to Stern (1968, Vol. III:55-95).

2.2.3.1. Terrestrial Plants and Pollution

Investigations in both Europe and America have shown that growth of plants is inhibited by air pollutant concentrations far below those at which obvious signs of damage occur. Photosynthesis is inhibited to varying degrees by many gases, including sulphur dioxide (SO_2), ozone (O_3), hydrogen cyanide (HCN), and hydrogen fluoride (HF). In zones of heavy particulate contamination, photosynthesis may be

reduced to one-tenth of the normal rate due to coating of the foliage (Mellanby, 1967). Whether or not all species of plants are equally affected by the variety of contaminants in the air is still to be determined. Work conducted in California over the past twenty years has shown that certain plants are very susceptible to smog (citrus) yet others (gladiolus) can produce resistant varieties capable of withstanding greatly elevated pollution levels (Rich, 1964; Darley, 1969).

One of the photochemical secondary products derived from automobile emissions is ozone, the normal background concentration of which in the lower atmosphere is only 2.3 parts per hundred million (pphm). Experiments with tobacco and pine have revealed damage to tissue when exposed to a level of 6 pphm for six hours (Katz, 1967). Measurements in urban areas indicate levels of 32 pphm occur in the vicinity of congested streets (Tebbens, 1968).

Other pollutants known to produce signs of damage on foliage, inhibit photosynthesis, alter enzyme activity, and stimulate abscission, are (PAN), ethylene, nitrogen oxides (NO_x), sulphur oxides, fluorides and particulates. Not all of these derive from the automobile but are commonly to be found in urban atmospheres (Brandt and Heck, 1968).

As was noted previously plants growing in the city may experience a longer growing season, and in an area where pollution is present this may have disadvantages. The

prolonged activity of the vegetation will expose it to greater amounts of pollutants and thus cumulative effects may be important. It is known for instance that conifers are much more susceptible to injury and death in cities due to their evergreen habit. They are potentially active throughout the winter and also retain their foliage for several years. According to Darley (1966), the principal effect of particulate contamination is clogging of leaf stomata with resultant reductions in both photosynthesis and respiration which eventually leads to stunting and death. Those evergreens which hold their leaves for six to eight years suffer most in a heavily polluted location (Fitter, 1945; Skye, 1968). Thus pine (*Pinus* sp.) better withstand city life than do spruce (*Picea* sp.) due to their leaf retention time of only half that of spruce. The most tolerant conifer is the larch (*Larix* sp.) which is deciduous.

The ability of some species or varieties to survive in regularly polluted areas usually results from the possession of a metabolic mechanism to render substances innocuous once they enter the leaf tissue. Thus Lihnell (1969) found that SO_2 is converted to sulphate by birch (*Betula* sp.) and apple (*Malus* sp.) trees, and leaf analysis reveals concentrations of sulphur some two to nine times as great as would be found in rural specimens. Some deciduous plants are thus able to store excess compounds in a harmless form and shed them with their leaves in the autumn thus giving them a

further advantage over evergreens.

The importance of air contaminants in controlling vascular plant reproduction is exemplified by observations made of trees growing in the major squares of Paris (Tendron, 1964; Soulier, 1968). It was recorded that before World War II (around 1927) the blooming of the princess trees (*Paulownia* sp.) became abnormal due to buds dropping off before they opened. During the war when both industrial and domestic combustion sources were reduced and private cars largely immobilised due to lack of fuel, the trees regained their former spring-time splendour and subsequently retained their fruits to the normal season. However, shortly after the end of the occupation when economic activity returned to normal and atmospheric contamination levels rose again, the trees once more suffered bud-fall and erratic blossoming periods. The principal components believed to cause these changes are carbon monoxide (CO), and ethylene which act synergistically to influence plant growth hormones.

One of the most studied groups of organisms with respect to air pollution are the lichens (Skye, 1958; Brightman, 1959; Fenton, 1960, 1964; LeBlanc, 1961; Gilbert, 1965; Pearson and Skye, 1965). As a result of their mode of nutrition lichens are susceptible to damage from contaminants in the air and in rainwater. Many species accumulate toxic concentrations of various compounds, including metals, and experience acidic conditions each time it rains.

Brodo (1966) has summarised the basic trends observed in connection with the presence of lichens in urban areas:

1. Leprose lichens are apparently most tolerant of city conditions.

2. The closer to the city centre the poorer the condition of the specimen and the smaller the coverage of the substrate.

3. Lichens on neutral or alkaline substrates (nitrophilous species) are most common in cities.

4. The scarcity of lichens is highly correlated with the presence of industry and high density populated areas.

5. Most population centres display a trend of reduced humidity and increased air pollution from periphery to centre.

Barkman (1969) working in Amsterdam gave the decline in numbers of species since the turn of the century as fifty-five and attributed this widespread extinction to increased industrialisation and motor traffic. Gilbert (1965, 1969, 1970) has demonstrated the lichen "desert" which exists in England, centred upon the Newcastle coalfield. It is possible to obtain close correlation between the absence of certain lichen species and the ambient levels of SO_2. Workers in other cities have noted a similar distribution of lichens (LeBlanc, 1961, 1969, Montreal; Brodo, 1966, New York; Laundon, 1967, London; Skye, 1968, Stockholm).

Not only the distribution but also the gross morphology of individual specimens is affected, and more importantly, their reproductive apparatus. Specimens inspected in heavily polluted zones are usually lacking in apothecia and are thus sterile (Skye, 1968; LeBlanc, 1969).

Skye (1968) has noted that the pH of tree bark is often sufficiently acid to prohibit the presence of lichen vegetation in central Stockholm. The rain tracks on city trees are usually devoid of lichens whereas horizontal branches may possess quite rich ephiphyte cover due to the more favourable substrate conditions they provide.

The principal effect of SO_2 upon lichens is thought to be damage to the algal chloroplast thus reducing photosynthesis. Syratt and Wanstall (1969) have demonstrated that this gas affects certain bryophytes more than others and the difference stems from the ability to metabolise the SO_2 to sulphates. This gas causes breakdown of the chlorophyll and if exposure is prolonged, death will result. Those species that can withstand high levels of SO_2 possess large amounts of chlorophyll and in addition are able to convert SO_2 to sulphate in large quantities without harm to the tissues.

Other simple organisms may also be excluded from urban areas due to pollution levels. On the subject of urban fungi little has been documented but it appears that basidiomycetes are not well represented and this may stem from low humidity and unsuitable soil conditions. The lack of dead timber in the city green spaces may also be important in this respect. Moulds and rusts while not commonly seen on city vegetation, are often observed in the home thus indicating the presence of viable spores in the atmosphere. That fungal infection is restricted by the urban environment is

demonstrated by the lack of attack suffered by juniper (Juniperus communis) growing in polluted areas of London and black-spot fungus (Diplocarpon rosae) is rarely seen on roses growing in polluted areas near industry (Air Pollution, 1969; 238).

Lead (Pb) is a commonly occurring air pollutant about which a considerable literature is beginning to emerge. The spur to interest came from the finding of elevated levels of this element in soils and vegetation along heavily used highways. Isotopic identification revealed the source of lead as lead alkyl additives used in gasoline and emitted to the atmosphere in the exhaust gases (Cannon and Bowles, 1962; Purves, 1966, 1967; Ruhling and Tyler, 1968; Kloke and Leh, 1969; Chow, 1970; Lagerwerff and Specht, 1970). Accumulations of other metals such as zinc (Zn), mercury (Hg), cobalt (Co) and nickel (Ni) are now being studied.

Mosses have been used in checking levels of lead in the environment since they rely upon precipitation for most of their mineral nutrients. Work in Sweden has shown that roadside specimens contain lead in concentrations of 300-500 ppm. Following a study of the lead content of mosses growing in central and southern Scandinavia, Ruhling and Tyler (1968:338-339) concluded that "the lead concentration of the mosses increases with precipitation and with decreasing distance to large population centres." By analysing museum specimens and material from peat bogs the Swedish researchers

found that the background levels of the lead are small and the currently measured concentrations are the result of human activities in urban and industrialized areas.

Brandt and Heck (1968) and Otto and Daines (1969) have pointed out that plants are affected by pollutants to varying degrees dependent upon other environmental factors occurring at the time of exposure. Thus soil nutrient status, soil moisture, and relative humidity, in addition to radiation intensity will all exert an influence to modify the effect of the pollutant. It has been shown for instance that injury is reduced in sensitive plants if they are relatively dry during exposure. The generally dryer air to be found in the city may thus counteract potentially damaging pollutant levels to some extent.

It is thus clear that care is necessary in judging or predicting the degree of damage likely to occur to plants in urban areas. Their potential use as indicators of general contamination levels is great and may allow trends of increasing pollution to be detected at relatively low cost and hopefully controlled before public health is affected.

From these scattered observations of the interaction of vegetation and air pollutants it may be concluded that where traffic congestion is a regular feature and both domestic and industrial emissions exist, plants are likely to suffer reduced growth and may be unable to reproduce.

The use of vegetation in cities both as an indicator of pollution level and a possible means of reducing certain pollutant concentrations demands further investigation. Lihnell (1969) believes that analysis of vegetation and mapping of the results can produce a reliable picture of SO_2 distribution from an isolated source. Gilbert (1970) has devised an index of lichen species which he feels can be used for determining areas of high SO_2 pollution.

2.2.3.2. Terrestrial Animals and Pollution

It should be recalled that all animals are ultimately dependent upon plants for food and many require vegetation for cover and nesting. Any change which brings about a modification in the species presence of plants may then have an effect on animals higher up the food chain, be they herbivores, omnivores, or carnivores. It is therefore possible for both direct and indirect effects to be experienced by animals living in a polluted area.

There are now a great number of documented cases of both fatal and chronic effects resulting from exposure to severe air pollution conditions. Perhaps the two most infamous occurrences took place in Donora, Pennsylvania in 1948 and in London, England in 1952 (Stokinger and Coffin, 1968). In addition to the large number of human fatalities some documentation of effects upon pets and livestock was taken. It was noted that in both instances canaries were

highly susceptible as also were dogs. Chickens and cats seemed less affected but many cows were reported to suffer acute respiratory distress and a few died of heart failure.

Veterinary research comparing rural and urban pet dogs has produced some interesting results which suggest that the latter suffer diseases and ailments attributable to their polluted environment. In a three year survey of 1,007 dogs in Philadelphia and its suburbs, Reif and Cohen (1970) showed a higher frequency of pulmonary disease in city dogs than in rural ones. This was most noticeable for middle aged and older animals. Ragland and Gorham (1967) demonstrated the prevalence of carcinoma of the tonsil in city dogs and suggested the need for studies to establish the relationships of atmospheric carcinogens to distribution of affected animals.

Much of the experimentation in connection with pollutant effects has been done with laboratory animals such as rats, mice, guinea pigs, rabbits and chickens. The emphasis has been on the determination of toxic levels and it is clearly unreasonable to extrapolate directly from such studies to the wildlife which exists in cities. Nevertheless, it is very possible that chronic effects due to air pollution are present in many urban animals and have yet to be investigated. Most of the substances which are known to be present in urban atmospheres have been studied in laboratory tests.

2.2.3.2.1. Urban Air Pollutants

2.2.3.2.1.1. Ozone (O_3)

Stokinger and Coffin (1968) refer to this gas as a toxic, fast-acting pollutant with long-term insidious potential effects for all forms of animal life. Tests with mice and rabbits showed that low-level daily exposure to ozone, or infrequent high level exposure produced permanent lung damage and in addition the mortality rate was increased in litters where the mother had suffered such exposure during pregnancy.

2.2.3.2.1.2. Sulphur Dioxide (SO_2)

Stokinger and Coffin (1968) believe that there is unlikely to be permanent detrimental effects due to the presence of this gas at its present level of concentration in urban atmospheres. Reports from Czechoslovakia from an industrial area where this gas is periodically present in high concentration indicate that hares (*Lepus* sp.) may suffer lowered reproduction rates (Nováková, 1969).

2.2.3.2.1.3. Nitrogen Oxides (NO_x)

These oxides are not considered to reach dangerous levels in cities at the present at least insofar as public health is concerned.

2.2.3.2.1.4. Carbon Monoxide (CO)

This odourless, colourless gas is highly toxic and causes reduced respiratory capacity due to its preferential

combination with haemoglobin. Current research suggests that low level cumulative effects do not occur in either humans or laboratory animals. Whether or not this will also hold true for urban species such as sparrows and pigeons which frequent roadsides where they may be exposed to high levels of CO has not been investigated. There is evidence that adaptation to low level exposure does occur in dogs and thus it may be possible that truly urban species will exhibit a tolerance to CO in the air (Morrow, 1964).

2.2.3.2.1.5. Hydrocarbons

These compounds derived from combustion of fossil fuels are involved in the formation of smog. Their principal effect on animals is eye irritation and lachrymation. Some of the hydrocarbons, such as benz-pyrenes and related polycyclic compounds are known to be carcinogens. In conjunction with inert particulate matter these compounds have been found to produce lung tumours. It is also believed that viruses in some way interact with these large organic molecules to produce carcinogenic effects in animals.

2.2.3.2.1.6. Heavy Metals

There is a scarcity of information concerning the effects of an increasing dissemination of metals in aerosols. An interesting piece of work conducted in Pennyslvania may lead to an increased use of wildlife in cities as pollution indicators. Tansy and Roth (1970) studied the levels of

metallic lead occurring in the hard and soft tissues of city pigeons and compared these to levels existing in rural populations. Their findings revealed a great difference in degree of accumulation of lead between urban and rural individuals, thereby indicating the variation in exposure at the different locations. Pigeons from central Philadelphia had two to five times the amount of lead in their tissues than rural specimens.

2.2.3.2.2 Effects of Pollution on Sensory Receptors

Olfactory and auditory senses are very important to mammals other than man and for them vision is but one mode of sensing environmental stimuli. With the number and variety of atmospheric pollutants it is conceivable that urban foxes, for example, suffer a decline in the acuity of their sensory organs which may be detrimental (Mellanby, 1967).

With respect to noise levels in cities there is a growing concern over the possible deterioration of hearing and stress effects upon humans but there has been no work on the effects of noise on other animals. In surveying the various records of nesting and breeding sites there is little indication that animals or birds shun noisy situations. Foxes are recorded raising litters under a shed on a building site and on railway embankments; songbirds have nested in trucks, aircraft, cranes, tractors, and cars, even when these are still in active use (Bridgman, 1962; Brown, 1963; Gladwin, 1963; Teagle, 1967, 1969). Land adjacent to heavy industrial

premises or airports which bears attractive vegetation cover is utilised by a variety of creatures which appear unperturbed by high noise levels (Murton and Wright, 1968).

2.2.3.2.3. Pesticides and Polychlorinated Biphenyls (PCB)

It has been suggested that less use is made of insecticides, herbicides, and poisons in urban areas than in intensively farmed regions. No documented evidence with which to directly verify this statement has been found although intuitively it appears reasonable. However, the affluence of the suburbs and the obsession with cleanliness may have resulted in relatively heavy pesticide use (Niering, 1969). Fahey *et al.* (1965), commenting on pesticide contamination of urban soils, believed that in the city a wide variety of products would be applied by inexperienced users resulting in a great range of dosages and possible abuse. Additionally there is a widespread belief that preventative spraying is needed and many preparations sold for domestic use serve a dual purpose, acting both as a fertiliser and a biocide. The principal pesticides used extensively for more than thirty years are now widespread throughout the systems of this planet. Tarrant *et al.*(1968) reported levels of residues in samples of rainwater taken at widely separated locations in Britain over a twelve month period and showed that urban atmospheres due to their high carbon particulate content had relatively large amounts of chlorinated hydrocarbons present. London rainwater

was more contaminated than that collected at rural sites where extensive agriculture was practised but somewhat lower than in districts such as the Kent fruit-growing area.

Many municipalities have spray control programs for weeds and fungal diseases in addition to mosquitoes. Tabor (1965, 1966) reported that pesticide levels of urban atmospheres are sufficiently high in some parts of the United States to represent a potential public health hazard.

Perhaps the best known member of the chlorinated hydrocarbon group is the pesticide DDT. It is a persistent compound whose residues are less directly toxic than their precursor but equally long-lived and capable of physiological side-effects which perturb ecosystems (Anderson *et al*. 1969). Many raptors, particularly those preying upon other birds or fish have accumulated concentrations of DDT and its metabolites to levels which have rendered the species infertile due to disturbances in the hormonal system controlling egg production. With the advantage of hindsight it is possible to suggest that the first symptoms of DDT accumulations were recorded in 1949 by Hall who studied peregrine falcons (*Falcus peregrinus*) nesting on a building in Montreal (Hall, 1970). These birds had successfully nested at this site since 1936 but suffered increasing difficulties from 1949 to 1952 when they finally disappeared from the city locale. Use of this biocide in Wisconsin to control Dutch elm disease in cities resulted in 80-90 per cent mortality of local robin (*Turdus*

migratorius) populations which fed upon earthworms in the soil beneath the sprayed trees (Hickey and Hunt, 1960; Wallace, *et al*. 1961; Hickey, 1966). Predatory invertebrates may similarly accumulate toxic levels of these compounds and a depletion of their numbers is usually accompanied by an even larger explosion of their prey population which may potentially be a pest (Edwards, 1965).

For wild animals the period of the year when an accumulation of chlorinated hydrocarbons is likely to be important is during winter and spring when food is scarce and temperatures low. Utilisation of fat deposits may release large quantities of the toxin into the blood stream and death can result. Recently, Cooke (1970) documented experiments in which tadpoles of the common frog were shown to be most susceptible to stored DDT at the time of metamorphosis. It is presumed that metabolism of fat reserves results in the release of toxic concentrations of the pesticide causing a high mortality among young frogs.

In addition to spraying of biocides there is now recognised an industrial and domestic source of chlorinated hydrocarbons. Risebrough (1970) reported that polychlorinated biphenyls (PCB) are widespread both in the atmosphere and hydrosphere following their increasing manufacture and use since the 1940s. These compounds find their way into natural systems by emissions and effluents from urban areas and thus may represent a particular hazard to animals

frequenting these places. The close chemical similarity of PCB to DDT makes their potential effects somewhat predictable, although experimental work conducted to date indicates that effects such as shell-thinning do not result from high levels of PCB in tissues of birds (Risebrough et al. 1970). Nevertheless, it is suggested that delayed breeding in birds may be an environmental effect attributable to these industrial biocides.

Clearly we need a great deal more information with respect to levels of chlorinated hydrocarbons in urban ecosystems and their realised effects. It may be argued that birds wintering in the city where weather is milder may be less exposed to acute pesticide effects. However, the longer term influence on reproductive capability of the species may be affected and should be investigated. It is important to bear in mind that for many birds and small mammals only the toxic effects of pollutants are relevant since these animals are relatively short-lived and may not experience cumulative effects. The average songbird lives some one to two years only and thus is unlikely to display signs of chronic pesticide poisoning. Very few wild creatures ever enjoy their potential life span since it is invariably cut short by accident, disease, or predation. However, the long term effects may be significant for larger mammals whose average life span is of the order of ten years.

2.2.3.3. Aquatic Ecosystems and Pollution

Historically, urban development has concentrated near waterbodies which provide drinking water supplies, transport, power, and a diluting medium for wastes. Since in many instances the accompanying flat land was subject to periodic flooding it was expedient to dike and drain extensively to facilitate building. Coastal areas have suffered considerable physiographic modification in the name of progress by activities such as in-filling to create more land.

The outcome of years of development is a lack of wetland and open-water in many urban regions except perhaps for a number of small ornamental pools. In addition, extensive sections of river have evolved as open sewers incapable of supporting a living community save for the lowliest members of the decomposer chain. Introduction of large amounts of organic material to the waterways has resulted in depleted oxygen levels due to excessive bacterial decomposition activity. In less drastically changed waters there is a trend toward greater productivity due to the increased input of heat energy and nutrients in the form of effluent and sediments. The total effects of growth in urban areas upon water resources vary considerably dependent upon the degree and type of industrialisation associated with the settlement.

In this century we have witnessed a growth in the rate at which metals are dispensed directly to water courses and indirectly via rainfall. Persistent biocides now

contaminate all waters adding a burden which we have still to evaluate fully. The common result of these several inputs to the aquatic system is one of simplification in the community of living organisms. Species typical of the early successional phases are abundant and productivity is high (Hynes, 1960, 1965; Mackenthun, 1969; Wilbur, 1969).

Construction in urban areas gives rise to erosion thus producing large quantities of sediments in stream and rivers of the watershed. In the United States this aspect of water pollution has been studied and recognised as a significant problem. Wolman and Schick (1967) calculated that developed areas in Maryland produced from 1-75 times more sediment than rural agricultural districts. Similar figures are available for other East Coast locations (Felton and Lull, 1963; Guy and Ferguson, 1970).

Another virtually unrecognised source of water pollution in residential area is that from surface drains which handle large quantities of oil and grease from parked vehicles, de-icing compounds applied to roads, road marking paint containing metals such as chromium, detergent from on-street car washing, and the excreta of pet animals.

It is recorded that New York City has a registered dog population of 500,000 and London boasts 700,000 (Time, 1970, 96(3):35). These are obviously minimum figures since unregistered and stray animals are unaccounted for. A minimum estimate of the quantity of urine finding its way into the

city environment each day is 22,000 gallons (New York) and 30,800 gallons (London). Similarly the estimated amount of faeces deposited would be in the order of a minimum of 125,000 lbs. per day in New York and 175,000 lbs. per day in London. Clearly this makes a significant contribution to the amount of untreated sewage reaching city watercourses and may considerably influence the metabolism of urban vegetation.

2.2.3.4. Interaction of Organisms in a Polluted Environment

The pronounced influence of chemical pollutants upon vegetation must be important to animals utilising it. Stokinger and Coffin (1968) provide data on the health of livestock which had been fed contaminated forage. In areas of fluoride contamination with ambient concentrations of parts per billion (ppb) it is possible for vegetation to accumulate toxic levels over a long period of time. There are accounts for Canada of deer (*Odocoileus virginianus*) suffering poor health due to living in the vicinity of a plant emitting fluorides. The animals were seen to drink regularly from effluent ponds containing fluoride concentrations of 4000-7000 ppm. Few animals lived beyond two years of age and had broken teeth and fractured jawbones (Karstad, 1967). Investigations of livestock in Czechoslovakia showed high fluorine levels in the bones, teeth and milk of animals exposed to polluted air. Sparrows, frogs, and rats in the area were also checked and found to contain two to fourteen

times the concentration of fluorides detected in similar animals from a clean area (Balážová and Hlucháň, 1969). Other substances such as Arsenic (As), Lead (Pb), Molybdenum (Mo), Berylium (Be), Manganese (Mn), Zinc (Zn) and Selenium (Se) can be concentrated in vegetation where they are potentially dangerous to animals. From Germany come reports of deer and hares poisoned by eating arsenic contaminated vegetation near smelters (Air Pollution, 1969). In general, however, there will be less ill-effect from ingestion of contaminated vegetation than from direct inhalation of pollutants due to the different protective physiological mechanisms which exist.

The species diversity of insects is markedly reduced in districts with heavy pollution. Vegetation coated with particulates will support less animal life than "clean" plants and polluted water will not provide suitable conditions for the larvae of most insect species. Lack of specific food plants curtails the number of moths and butterflies able to live in such an area and produce offspring. For example, Nováková (1969) has produced preliminary evidence for a decreased incidence of insects in industrialized areas of Czechoslovakia.

Reports from London suggest that particulate pollution is an important factor limiting flying insect populations (Gooders, 1968). Since the introduction of smoke controls in 1954 there has been a noticeable increase in the number of swifts (<u>Apus apus</u>) and house martins (<u>Delichon urbica</u>) in

districts close to the city centre. In the past these birds were seen to be gradually retreating from the inner city as a result of the presumed lack of food. Gooders (1968), however, believes that the return of these birds is related to reduced particulates in the air. In view of the swift's mode of feeding which involves flying open-mouthed collecting all objects in the flight path it may not be too surprising to find them absent from smoky areas. From evidence cited earlier, the soot particles are heavily contaminated with pesticides and also accumulate sulphur compounds thus they may have quite devastating effects upon such a bird as the swift. Nevertheless, it may also be presumed that improvements in air quality may have allowed a concomitant increase in the flying insect population to the benefit of the swift.

The current appraisal of herbicide use suggests that it has rarely had direct effects upon animal life but certainly has been instrumental in removing particular plant species from local flora thus destroying necessary food or cover for animals (Moore, 1965; Way, 1969). An exception to this is the influence of chemical spraying on bees (*Apis* sp.) whose essential pollinating activities have been halted over extensive areas through mortality. Use of sprays during the flowering period means that toxic concentrations can collect in the base of the flower cup and when bees take nectar they also absorb high concentrations of chemical (Way, 1969). Such mortality can be avoided by careful timing of spraying

to avoid the flowering period. By a similar mechanism bees are exposed to fatal doses of arsenic, zinc and fluoride in areas where these metals appear in aerosol form (Tendron, 1965).

One detrimental result of herbicide use, as yet only observed in livestock but potentially of interest when considering wild herbivores, is the increase in palatability exhibited by usually toxic plant species. Through some unknown mechanism, herbicides can render a normally unpalatable plant attractive to herbivores but the inherent toxicity remains unchanged thus increasing the chance of the animal ingesting fatal doses of the toxin (Mellanby, 1967; Way, 1969).

As a result of the widespread military use of 2,4,5 - T as a defoliating agent, studies have been instituted to discover the cumulative, chronic effects of its presence in the environment. Preliminary evidence shows that impurities in the compound, chlorinated dibenzo-p-dioxins, induce embryonic deformities and mortality in chicks (Risebrough *et al*. 1970).

With an increasing use of herbicides both in agriculture, wildlife management, and in domestic gardens, we cannot disregard the possibility that there may be as yet undetected changes in wildlife populations (Persson, 1968; New Scientist, 1970, 49:593). An important point that must always be remembered concerning wild animals is that while chronic effects may be unimportant in domestic or laboratory animals they can appreciably affect the viability of a truly wild individual.

Anything which reduces its competetive ability even for a limited time may make it vulnerable to other constraining factors in its environment.

In conclusion, it is important to reiterate the point made earlier: when assessing damage to plant and animal life in any habitat, consideration must be given to the whole complex of environmental factors. The effects of pollution will differ according to the age of the specimen, its physiological condition at the time of exposure, the frequency of such exposure, and its physical environment, particularly the nature of the local climate. Besides the direct impact of pollution there may be ecological disruptions. Reduction in species diversity or even extirpation of species can have far reaching results if trophic relationships are thereby upset. We are extremely ignorant of the full impact of the urban environment upon any living organism beyond the point of knowing that it is inhospitable to a wide spectrum of species.

2.3. Characteristics of Urban Flora and Fauna

2.3.1. The Response of Organisms to the Urban Environment

Many of the animals which have been designated "pest" commonly possess the ability to adapt to changing conditions. The "ecotonal" species, those possessing a wide range of tolerance to various environmental factors, are most likely to be capable of co-existing with man. These plants and animals are often able to reproduce rapidly and take advantage of

transitory conditions or evolve varieties suited to the urban situation. Animals with flexible behavioural patterns such that they are able to exploit new food sources, new nesting or roosting sites, and can avoid novel forms of predation may also be expected to colonise city habitats. Such intrinsic behavioural plasticity is possessed by many mammals and birds, allowing adaptation to occur within the lifetime of the individual without actual genetic change. Titmice (Parus sp.) are good examples of such species with an ability to learn from observation, and it is possible for innovative behaviour to spread rapidly throughout local populations.

Discovery of novel sources of food is well exemplified in the case of the British blue tit (Parus caeruleus) which in the 1940s developed the habit of stealing cream from milk bottles (Fisher and Hinde, 1949). Similar reports have come from Norway where the great spotted woodpecker (Dendrocopus major), jackdaw (Corvus monedula), magpie, and blue tit open milk bottles (Abro, 1964). It has been suggested that this type of behaviour may result from an inborn tendency to hammer at hollow objects.

Another type of change is seen in some of the smaller diurnal mammals which have become quite tolerant of people to the point where they may take food from the hand (Lond. Nat., 1968, 47:33). The grey squirrel in city parks has been tamed in this way yet still retains the essential degree of wariness necessary to protect it from danger. Indeed it has been so

successful in this habitat that some municipal authorities (New York for example) classify these animals as pests.

Very few animals except perhaps the common rat (*Rattus novegicus*), house sparrow and feral pigeon are found only in close association with human settlements. The ability of the sparrow to follow wherever man establishes new roots is demonstrated by the rapid spread of this bird following its introduction to America in 1850. Summers-Smith (1963) has discussed in detail the characteristics and achievements of the house sparrow in colonising urban areas. The pigeon's commensal relationship with man has evolved over several centuries and Gompertz (1957) has suggested that the feral pigeons have merely exploited changed human behaviour rather than undergone change themselves. Their rock dove ancestors live on cliffs using caves for nesting, and fly to adjacent farmed areas to feed. The feral birds live on man-made cliffs and utilise scraps and refuse which accumulate in the city habitat (Goodwin, 1954; Murton and Westwood, 1966).

When organisms achieve pest status it is not always the result of adaptation. It has been noted by Newman (1966) that ants have often survived and grown to noticeable populations because their predators have proved much more sensitive to the built environment. It is probable that this applies to many insect species.

Animals displaying the least ability to co-exist with *Homo sapiens* are his direct competitors, the carnivores. These

mammals were the first to be driven away or exterminated when an area was settled. The larger the animal, the more likely that conflict will be intense and the limited distribution of animals such as bears (Ursus sp.), wolf (Canis lupus), cougar (Felis concolor) and lynx (Lynx canadensis) exemplifies the result. Few carnivores can tolerate high levels of disturbance and are driven from their old haunts as peripheral sprawl occurs. They are most likely to survive in those situations where housing encroaches upon areas of sharp relief thus creating an abrupt juxtaposition of the built and natural environments. What could be described as the medium-sized carnivores are very successful in the peripheral suburbs; typical species are the English fox and the American coyote (Canis latrans) (Teagle, 1967; Gill, 1970).

Another reason for the survival of some animals in the city is their nocturnal behaviour. Provided that adequate habitat is retained such creatures can thrive even though they may be intolerant of direct human disturbance. The omnivorous habit also bestows an advantage allowing animals to exploit the wide range of food resources readily available in the city.

2.3.1.1. Exploitation of Man-Made Structures by Animals

Buildings are used by animals primarily for breeding and roosting activities. A few species such as some insects and rodents may live their entire lives within buildings, however most utilise them intermittently since they require

other habitat areas for feeding.

Starlings have adopted city centres as primary roosting places and in major capitals of Europe and America have achieved pest status due to such behaviour. In London, the first indications of this change of roosting site were recorded in 1894, when starlings were seen gathering in the trees of St. James's Park (Johnson, 1930). As the number of individuals increased, a movement from the trees to the ledges and sills of adjacent buildings was witnessed. Today considerable expense is incurred by municipalities trying to dissuade the starlings from using buildings and in clearing up the results of this activity. The city roost is preferable to a rural one because night-time temperatures are higher, there is an enormous footage of suitable ledges and these high perches offer relative safety from predation. Potts (1967) listed fifteen built-up areas in Britain where starlings roost on masonry, but concluded that this only accounts for some five per cent of the total starling population in the country.

Bats which originally roosted in hollow trees or caves have always found buildings quite acceptable substitutes, particularly favouring church spires and bell towers. Dilapidated houses with attics are often found to harbour large numbers of bats which occupy them all year round (Hancock, 1963; Beames, 1968). Some grey squirrels in London have taken to living in the roof spaces of houses during the

winter and similar records exist for Toronto (Lond. Nat., 1965, 44:54; Cox, 1970).

Pied wagtails (Motacilla alba) have recently invaded the Hammersmith area of London where they roost on buildings in flocks of some 120 individuals (Lond. Bird Rep., 1970, 34: 58). A report from a sewage purification works in London's Lea Valley indicates that some four hundred wagtails roost at this site (Gladwin, 1963).

Roofs, parapets and ledges of city buildings have served as nesting sites for many birds, including kestrels (Falco tinnunculus) in London (Lond. Bird Rep., 1968, 32:84), peregrine falcons in Montreal, Chicago, New York, Boston, Philadelphia and Harrisburg (Groskin, 1952; Hall, 1970), sparrowhawks (Falco sparverius) in Washington, D.C., wood-pigeons in London (Peal, 1965), lesser black-backed gulls (Larus fuscus) in Gloucester, England (Owen, 1967), and feral pigeons in most cities. It is clear that many cliff-dwelling species find the built environment a very acceptable substitute for natural habitat; indeed, some species appear to prefer it.

In the wild, holes are utilised by many avian species for nesting purposes and old timber is a prime source, as are sandbanks, riverbanks and caves. In the city none of these native sources occur in any quantity thus forcing the birds to adapt to different structures if they are to survive. Holes in the metal framework of power stations, gas holders,

railway stations, warehouses and other industrial sites are repeatedly used for nesting. Timber yards prove to be excellent habitat as do ruined or bombed buildings, quarries and gravel pits. In London the black redstart (Phoenicurus ochruros) has exploited most of these structures and successfully reared offspring at an increasing rate in the last thirty years (Meadows, 1965, 1970). In England, blackbirds, feral pigeons, and house sparrows are frequently seen nesting in railway stations, bus terminals, and other public places using the metal girders as though they were tree branches. Magpies and kestrels have been seen nesting in the framework of a construction crane and despite continual operation were reported to have fledged young without undue losses (Fairhurst, 1970). Other sources of holes regularly used by the house sparrow include neon display signs, lamp standards, utility poles, bus stop signs, roof eaves, drain pipes, ventilator hoods and bridges. Other birds which have availed themselves of these artificial sites include swifts, woodpeckers, sand martins (Riparia riparia), titmice, English robins and starlings.

Fischer (1958) has described the successful nesting of the chimney swift (Chaetura pelagica) which in days before man built houses with chimneys, frequented caves, rock crevices, and hollow trees. Gooders (1968) describes the house martin as predominantly breeding on man-made structures, particularly under roof eaves and bridges.

Persistent use of man-made structures is much less common among mammals although there are reports of foxes using old cars as artificial earths. In speaking of the adaptability of suburban foxes in England, Teagle (1967) mentions the use of old sheds, shacks, drains, scrap yards and dumps for the rearing of cubs. Rats and mice are the only species which have adopted buildings as their principal habitat.

2.3.1.2. Exploitation of Man-Made Structures by Plants

At first sight it would seem unlikely that plants would take advantage of the built environment but the botanical literature reveals examples of many species which adapt to life on walls. While a few of the plants found on walls may be described as mural species most tend to come from parks and gardens, meadows, hedges and woodland. It appears that certain types of walls become a "refugium" when the native habitat is destroyed by urban development. Some of the interesting points in wall ecology are dealt with by Kent (1961) in his paper on the flora of Middlesex walls (London area). He notes that in Cambridge some 186 species have been reported growing on walls, in Durham there were 168, and his own work showed 204 species. In other areas of London 70 walls supported some 83 species indicating that this type of substrate is an important component of the city habitat. Kent (1964) presented further information on the

ecology of churchyard walls which he believes support a relict native flora. Laundon (1970) studied lichens in the London area and pointed out the relative importance of structures such as limestone memorials in churchyards and asbestos-cement roofs which provide an alkaline substrate for these plants.

2.3.1.3. Exploitation of Food Resources

Adaptation to new resources is commonly displayed by birds in urban areas (Harrison, 1960; Bergman, 1961; Brown, 1964; Williams, 1964; Beven, 1965; Yalden and Jones, 1970). Studies in England have shown that tawny owls (*Strix aluco*) utilise different food sources dependent upon prey availability in the area of residence. Rural individuals have a diet comprised principally of small rodents (shrews, field mice and voles) with birds contributing only 10 per cent or less. Their urban counterparts by contrast, unable to find large quantities of small mammals, depend heavily upon local sparrow, starling and pigeon populations. The relative proportions for London owls is 93 per cent birds and 7 per cent rodents (mainly rats and house mice); such reversal of diet has also been confirmed in Paris and Manchester (Guichard, 1957).

Other predatory birds living in inner urban districts are kestrels and peregrine falcons which from the scanty evidence available appear to be similarly dependent upon these common passerines (Groskin, 1952; Green and Forsyth,

1970). Ljunggren (1968) observed that urban wood pigeons in Sweden were less subjected to predation from carrion crows (Corvus corone) than their rural counterparts, a fact which he believed to be related to the numerous alternative sources of food available to the crows.

The alacrity with which birds take household scraps and the more recently offered "wild" bird foods in garden feeders indicates that these are highly acceptable energy sources. Murton and Westwood (1966) analysed crop contents of feral pigeons in Leeds and found that bread, cake, cereals, and exotic grass seeds were the principal components. Ljunggren (1968) and Cramp (1968) have confirmed the importance of bread as a dietary component for city wood pigeons in both Sweden and England. There is, however, some indication that such a resource is inadequate during the breeding season. Titmice appear to utilise city food during the winter, and return to their natural woodland habitat to raise their young on the protein-rich and abundant caterpillar populations (Perrins, 1968).

The growth in number of sewage outfalls, garbage dumps and other waste ground feeding sites has resulted in a concomitant increase in the populations of certain species throughout Europe and America. Many gulls have become winter residents in urban areas and some remain to breed in central London (Meadows, 1961; Sanderson, 1968; Sage, 1970). Gibbs (1963) studied rubbish dumps as a wildlife habitat and lists

the principal species in the London area as gulls (Larus sp.), crows (Corvus sp.), the house sparrow, starling, feral pigeon, kestrel and pied wagtail. Flocks of gulls in excess of 4,000 were seen at the larger dumps and kestrels were attracted by the large rodent population.

Strawiński (1963) pointed out the attractiveness of meat-packing plants to members of the Corvidae and noted the gatherings of seed-eaters around warehouses, docks and food-processing factories in Poland. Pigeons commonly frequent docks to feed upon spilled grain and manage to find adequate nesting sites inside warehouses. Sparrows exploit similar resources and are reported to be resident in bakeries, food processing plants, cafeterias and canteens (Thearle, 1968).

The diet of suburban English foxes is extremely varied and may include such items as fish from ornamental pools, vegetables dug from kitchen gardens, scavenged scraps from garbage cans, litter bins, bird tables, and compost heaps. One interesting adaptation is the frequenting of parking areas and transport cafes to pick up food left by all-night truck drivers.

It seems clear that man's wasteful practices have encouraged birds and animals with omnivorous habits to colonise urban areas. In their wake have come those predators whose behaviour is sufficiently flexible to allow them to accommodate to noise, disturbance, and pollution. McNab (1963) and Schoener (1968), following a study of feeding habits in

relation to size of home range, suggest that omnivores require a much smaller feeding area than do carnivores when compared on a body weight basis. This can also explain the incidence of colonial nesting among many omnivorous animals. In an urban area where the mosaic of habitat tends to be on a small scale it is perhaps unsurprising to discover the large number of omnivorous species which can be found (Table 2.3.1).

A generalisation which can be suggested about urban birds is that there is a high frequency of ground-feeding species. Ground-nesting species, however, are rarely successful due to the interference which they experience.

2.3.2. Mortality

Urban animals can meet their end in a variety of ways, many of which differ but little from those found in rural areas. The relative importance of the different forms is unclear since no detailed study has been conducted into this aspect of urban ecology. Table 2.3.2. provides a list of the various causes of mortality and the principal species so affected in London.

2.3.2.1. Impact

Ever since man first developed ways to transport himself at speeds faster than his own two feet would carry him, he has presented an increased danger to animals whether or not he was actually using the conveyance to hunt them. In the centre of towns injuries caused by cars are more usually

Table 2.3.1. - Urban Omnivores

Birds	Mammals	Invertebrates
Mallard (*Anas platyrhynchos*)	*Opossum (*Didelphis marsupialis*)	Cockroach (*Periplaneta* sp.)
Mute Swan (*Cygnus olor*)	*Raccoon (*Procyon lotor*)	Slug (*Arion* sp.)
Moorhen (*Gallinula chloropus*)	*Striped Skunk (*Mephitis mephitis*)	
Coot (*Fulica atra*)	Dog (*Canis familiaris*)	
Gulls (*Larus* sp.)	*Coyote (*Canis latrans*)	
Pigeon (*Columba livia*)	Fox (*Vulpes vulpes*)	
Crow (*Corvus* sp.)	Badger (*Meles meles*)	
Magpie (*Pica pica*)	*Squirrel (*Sciurus carolinensis*)	
Blackbird (*Turdus merula*)	Common Rat (*Rattus norvegicus*)	
Starling (*Sturnus vulgaris*)	Mouse (*Mus musculus*)	
Sparrow (*Passer domesticus*)		

*New World species

Table 2.3.2. - Causes of Death in the Urban Environment (London, U.K.)

Mode	Species Affected
DROWNING	
Sewage canals and tanks	Hedgehogs
Ornamental pools	Owls, Squirrels
Rainwater pipes and gutters	Sparrow chicks, Sand Martin chicks
IMPACT	
Vehicles - cars, trucks, buses, trains and aircraft	Foxes Hedgehogs, Squirrels, Weasels Rabbits, Deer, Songbirds Snakes, Insects
Structures - plate glass windows, T.V. masts, tower buildings and power lines	Songbirds, particularly migrants Waterfowl, Owls
ELECTROCUTION	
Railway Lines	Badgers, Rabbits, Otters, Foxes
Power transmission lines	Raptors, Swans, Geese
Neon display signs	Sparrows
POISONING	
Pesticides	Foxes, Badgers
Baits	Hedgehogs, Birds, Invertebrates
Heavy metal	Rodents, Songbirds
CONFINEMENT	
Litter - cans and bottles	Small Rodents, Insects
Netting	Blackbirds
PREDATION	
Cats, Dogs, Man	Rodents, Lagomorphs, Foxes, Reptiles
Kestrel, Tawny Owl	Songbirds, Amphibians
Crow, Magpie, Jay, Jackdaw	Pigeons, Doves
Fox, Weasel, Stoat	Waterfowl

Based on a survey of reports issued by LNHS, 1960-1970

incurred by humans but in the suburbs and on roads through large parks many small mammals and songbirds meet with fatal collisions. Some attention has been paid to the subject in an attempt to analyse the reasons for certain "black spots" which occur on many roads (Komarek and Wright, 1929; Scott, 1938; Pickles, 1942; Finnis, 1960; Hodson, 1960, 1962; McCann, 1960; Dunthorn and Errington, 1964). The existence of breaks in the boundaries along roads seems to present a hazard for birds which tend to swoop low from the gap and over the road surface where they are an intermittent target for fast moving vehicles. Trains also claim substantial numbers of larger ungulates in isolated urban areas close to wild country. Birds and animals are drawn to railway rights-of-way by grain spilled from cars, exotic grasses which become established, and by the open nature of these rights-of-way.

In the London area there have been reports of high casualty rates among hedgehogs (*Erinaceus europaeus*) which are small members of the Order Insectivora whose natural reaction to danger is to curl into a ball and remain still. Table 2.3.3. indicates the minimum number of deaths due to this non-adaptive behaviour in the London area. A naturalist in Lancashire, England believes that these creatures are now showing signs of adapting to this hazard due to the intense selective pressure operating (Lancs. Nat. Trust, 1970). Among other animals which regularly succumb on roads are the

Table 2.3.3. - Hedgehog (Erinaceus europaeus) Mortality on London Roadways

Year	Number Observed
1960	62
1961	50+
1962	66 (of this number 26 were reported from a single stretch of road, one mile long)
1966	199
1967	277 (of this number 100 were seen on a twenty mile stretch of road in Essex and 11 came from a one mile piece of road in a twelve week period)

Compiled from reports received by LNHS, 1960-1967

grey squirrel, weasel (Mustela nivalis), fox, snakes and innumerable insect species. Impact with static man-made structures is a problem for all avian species. A recent study of mute swans (Cygnus olor) in England, showed 40 per cent of deaths were due to collisions with overhead wires (Brit. Birds, 1970, 69:43).

2.3.2.2. Poisoning

The true effect of poisons and pesticides is unclear as there are few records of death directly attributable to this cause. One suburban gardener in London was filled with remorse when three hedgehogs were found dead in the flower bed one day after roses were sprayed with fungicide (Lond. Nat., 1969, 48:42). It is believed that badgers (Meles meles) in the London suburbs die from the toxins accumulated in their favourite prey, the earthworm (Teagle, 1969).

2.3.2.3. Confinement

Many small rodents have been reported to die trapped

in bottles and cans discarded in roadside ditches in the English countryside (Harper and Morris, 1965). Since such litter is even more ubiquitous in suburban areas it would seem likely that it may be a significant source of mortality.

2.3.2.4. Predation

One important repercussion of human behaviour upon wildlife in the city is the presence of large cat and dog populations which to some extent occupy the vacuum created by the exclusion of native carnivores. It is difficult to establish what degree of control or influence these domesticated animals have but the magnitude of effect is undoubtedly related to the number of feral individuals existing in any one place. The well cared for household pet is unlikely to exert any marked predatory pressure on rodents and birds in its locality but a neglected or truly feral cat has considerable influence. McKnight (1964) has reviewed the subject of feral animals and provided evidence concerning both the magnitude and diet of feral cat and dog populations in the United States.

2.3.2.4.1. Feral Cats

Each year many thousands of cats and kittens are abandoned thus creating a substantial feral population. Some drift into rural areas or are purposely "lost" in the country but many live within the urban environment utilising garages, sheds, vacant lots, and sewers as habitat. The food of feral

cats has been studied only in rural areas but will be somewhat similar in both locations. Rodents, particularly rats, are the principal dietary component with garbage and birds contributing only a minor portion of the total intake; rabbits are important items at certain seasons but may well be absent from the urban dweller's diet. Cats seem to be potentially a significant influence on rodents throughout the year in all locations, and on songbirds during the breeding season in suburban districts.

2.3.2.4.2 Feral Dogs

Here again most reports relate to rural animals where packs are commonly seen and these manage to kill deer thus enjoying a wild and successful existence. Feral dogs have, however, been recorded living in city slums, suburban parks, and in river valleys particularly where these areas serve as refuse dumps. Known dietary items of feral dogs include muskrat, waterfowl, rabbit, squirrel, pheasant, opossum and raccoon. An individual dog is of lesser account as a predator than a feral cat, however, since it more readily resorts to scavenging from garbage bins.

Recently in Baltimore, the first study of feral dog ecology was made (New Sci., 1971, 49[738]:289). Using standard techniques, the feral dog population density was calculated to be 600-800 individuals per square mile giving an estimated total of 80,000-100,000 individuals in Baltimore.

Habitat used by the dogs consisted of suburban shrubbery, junk-car yards, old buildings, and quiet rooftops. It was confirmed that domestic garbage provides the principal food resource but regular feeding by city residents significantly increases the available food. Home range of an individual dog was estimated as one square mile but packs of two to six were regularly seen. The investigator concluded that these dogs were already becoming a problem and the rapidly growing population threatened to present municipal authorities with some difficult decisions in the very near future. Public sentiment was likely to be involved if any attempt at mass extermination was suggested, but some controls would soon have to be exercised.

The role of cats and dogs as effective predators of the rat was previously discussed. Jackson (1951), working in residential areas of Baltimore, noted that an average cat caught between twenty-five and thirty rats each year and this had very little apparent effect on the population size of the prey. There is some scanty evidence that a positive correlation exists between the rat population and that of dogs and cats; an area able to support feral cats can equally favour rats (Peters, 1948). Backyard kennels which house domestic dogs may often attract rats since the adequate supply of food and shelter adds suitable habitat.

The population of dogs and cats in all cities is obviously large and is therefore an important component of the city ecosystem worthy of more study than has yet been

devoted to it.

2.3.2.4.3. Other Forms of Predation

Among frequently observed predators in European cities are the carrion crow, tawny owl, fox, kestrel, and weasel. In American cities, coyotes, striped skunks and raccoons (*Procyon lotor*) can be added to this list. Man is less often a direct predator upon animals in the city than he is in rural areas but children do represent a considerable threat to populations in local areas. The use of air guns, catapults, and the practice of egg collecting can all raise the level of predation so that it more closely resembles that experienced by rural populations (Yalden, 1965).

2.3.2.5. Seasonal Mortality

For animals in natural habitat the heaviest losses are believed to occur toward the end of the winter period as food supplies become exhausted or increasingly inaccessible. Urban-suburban fauna are apparently less affected by the deprivations of winter, and the heaviest adult mortality is found in the breeding season. Snow (1958) compared English blackbird populations living in woodland and suburban parkland and observed a lower adult mortality rate among the garden birds during months of winter. This altered seasonal mortality has also been confirmed by others (Havlin, 1963; Erz, 1964).

For most urban-suburban songbird species, adults die

predominantly in the breeding season while brooding or during their search for food to satisfy the nestlings, when it is believed they become less wary (Summers-Smith, 1956; Snow, 1958; Coulson, 1961).

Grey squirrels living in Toronto city parks appear to show a decreased winter mortality and again the shift is into the months of April-June (Cox, 1970). Information on other animals is yet to be collected but it is reasonable to expect the advantageous food resource and warmer temperatures of the city to produce comparable results.

2.3.3. Physiology and Behaviour of Urban-Suburban Mammals

This is an area where few scientific studies exist. Casual observation is the major source of information thus any interpretation can be only of a speculative nature.

Vesey-Fitzgerald (1965) suggests that suburban foxes in southern England have become noticeably diurnal, extending their activities into the late morning; they may regularly be seen loping across gardens on their way back to earth from their night-time hunting forays. It appears that these same foxes are breeding up to three months earlier than rural ones. This and other aspects of fox ecology should be subjected to closer scrutiny to determine causal influences. Presumably increased food combined with freedom from persecution have made such changes possible. To illustrate, Vesey-Fitzgerald believes that suburban vixens do not bother to move their

litter to a different earth shortly after birth since such behaviour is adaptive only when the animal is regularly hunted. In gardens of private homes the vixen is less likely to be disturbed but there may also be the problem of a shortage of fox earths in view of the high density of suburban populations.

Cox (1970) studied the grey squirrel in Queen's Park, Toronto, and concluded that human presence had caused changes in the animal's periods of peak activity. Lunch-time strollers usually fed the squirrels and certain local residents came each day throughout the year specifically for the purpose of feeding them peanuts. He noted that in wild habitat, grey squirrels were observed to be most active during the three hour period following sunrise and before sunset. Toronto squirrels displayed an additional noon hour period of activity during which the paths were the principal focus area.

2.3.4. Behaviour of Urban-Suburban Birds

English robins are known to become very tame and tolerant of human presence when seeking food. Many gardeners are familiar with this bird which closely attends any digging activity so as to capture the exposed worms and larvae. A more specialised piece of behaviour was reported from Holland Park in London where a robin whose territory included a log pile would immediately fly to the pile when a person approached and wait for a log to be turned over so that he

could snap up the exposed invertebrates (Brown, 1963).

From Poland, Dyrcz (1969) has discussed the predominance in built-up areas of the blackbird over the song thrush (Turdus philomelos) and believes this to be the result of a greater adaptability possessed by the former species. It is able to feed upon a wider range of materials and also accepts a variety of alternative nesting sites when living in areas devoid of shrubs.

There seems to be no evidence that new behavioural patterns emerge in the urban environment; there is instead a persistence of old patterns which are directed towards new resources (e.g. the titmice and milk).

2.3.5. Population Characteristics of Urban-Suburban Birds

There has been more written on the subject of birds in cities than on any other aspect of urban ecology, resulting presumably from the relative conspicuousness of avifauna. The mobility of these animals makes them better suited to the urban environment than most other forms. Work in America, Europe and Britain suggests that many songbirds are actually more successful in the suburban habitat; in well established residential districts even species diversity is moderately high (Strawiński, 1963; Woolfenden and Rohwer, 1969).

2.3.5.1. Songbird Density

The density of these species seems to be dependent upon the type of vegetation cover available. Areas where

stratified vegetation, buildings, arable and pasture land are interspersed with plentiful water sources can support a varied, high density population throughout the year. Table 2.3.4 has been compiled from multiple sources and shows the range of densities met with in different locations. It is clear that geographical location will fundamentally influence the potential density and more examples are required before any definite statements can be made concerning relative densities of urban and rural areas. Using the English blackbird as an example, it is clear that it attains its greatest breeding density in peripheral, residential districts of cities (Table 2.3.5). In some instances the difference may be as much as a fourfold increase over rural woodland populations (Havlin, 1963).

2.3.5.2. Songbird Clutch Size

The evidence so far available shows that suburban birds lay smaller egg clutches than members of the same species inhabiting woodlands and this has been documented for European titmice, blackbird, song thrush, robin and dunnock (*Prunella modularis*). The smallest clutches recorded are those from the inner city area. This is seen as an adaptation to the built environment since clutch size acts as an indicator of the sum total of the quality of environmental conditions (Snow, 1958; Havlin, 1963; Lack, 1965; Snow and Mayer-Gross, 1967; Perrins, 1968).

Table 2.3.4. - Man-Modified Habitat and Its Influence Upon Bird Density

Habitat	Breeding Density (pairs/10 acres)	Location	Source
URBAN-SUBURBAN			
Parkland	185.0	Wisconsin	Young, 1949
"	141.5	France	Ribaut, 1970
Campuses, estates and parks	av. 41.4	USA	Odum, 1959
Sportsground	34.4	France	Ribaut, 1970
Gravel pit	24.8-45.0	England	Glue, 1970
Inner City parkland	24.0	London	Lond. Bird Rep., 1968, 32:65-68
Town cemetery	72.0	Switzerland	Ribaut, 1970
Old suburban district	26.0	London	Simms, 1962
"	av. 55.0	Florida	Woolfenden, 1969
Suburb built in former park	49.4	Zeist, Holland	Bruyns, 1961
New suburban district	28.2	Dortmund, Germany	Erz, 1959
"	20.0	Florida	Woolfenden, 1969
RURAL			
Parkland	28.8	Poland	Havlin, 1963
Parkland-Farmland	44.6	England	Ribaut, 1970
"	27.5	France	Ribaut, 1970
Woodland (oak)	53.5	Scotland	Williamson, 1969
" (birch)	44.5	Scotland	Williamson, 1969
"	30.3	Switzerland	Ribaut, 1970

Table 2.3.5. - Population Characteristics of Blackbird (Turdus merula) in Different Locations

	England large garden	Czechoslovakia suburb	England dense oakwood	England farm-land	Czechoslovakia woodland	England urban district
Breeding season	1 - 2 weeks earlier than in woodland	10 days earlier				
Density of birds (Pairs per ten acres)	20.0	Four times that in woodland	2 - 3			
Clutch size	3.8	3.94		3.91	4.14	
Nesting success	50%	69%	12%	28%	62.4%	
Fledging success	83%		89%	81%		73%
Average number of young raised per nest	2.1	2.4			2.46	

Compiled from the following sources: Snow, 1958; Havlin, 1963; Snow and Mayer-Gross, 1967.

2.3.5.3. Songbird Nesting Success

This will depend upon a complex of factors of which habitat type is very important. The amount and type of cover and the time at which this becomes available will affect the amount of loss due to nest destruction and predation. Birds which habitually nest early and build bulky nests will be extremely vulnerable in urban areas where little understory vegetation exists. The earlier onset of the growing season in the warmer urban environment may help to explain the observed earlier nesting of several songbird species. In England, Snow and Mayer-Gross (1967) report greater success of both blackbird and song thrush in gardens when compared to woodland populations.

2.3.5.4. Songbird Nestling Mortality

It is recorded that great tits (*Parus major*) in urban areas experience a higher nestling mortality than do rural birds (42.5% to 33.0%). Due to the preferential survival of male nestlings, urban populations also possess a distorted sex ratio (Dhondt, 1970). While this finding requires further study it appears to be a consequence of inadequate feeding which increases the competition between the heavier-bodied male nestlings and their female siblings. This adds substance to the comments made elsewhere concerning the probable shortage of high-protein food necessary to achieve satisfactory fledging success. Only those birds capable of utilising new or different protein sources can be expected to enjoy

comparable success in both the urban and rural environments.

2.3.5.5. Songbird Success - A Summary

From the information so far available it seems that some species of birds enjoy greater success in suburban habitats than they do in their ancestral woodland. The factors involved are several and include availability of food, amount and type of cover, local climate, number and type of predators, and density and age of breeding pairs.

Food may often be the limiting factor which reduces the fledging success of urban-suburban birds. Blackbirds for whom the earthworm is a major dietary component seem able to find sufficient food in gardens and lawns during the early part of the breeding season which allows them to raise three or four offspring. The success rate declines as the ground dries out and less open ground is exposed. Titmice which tend to be arboreal feeders can rarely raise the eight or ten young commonly found in their native habitat. In the suburbs extensive woodland capable of producing the prolific caterpillar crop necessary for such birds is very rarely present (Perrins, 1968). Clearly the other important variable is the rate of predation including nest destruction. Again, it appears that urban individuals suffer less damage to their nests following construction and potentially higher nesting success is possible. The prime mortality during the breeding season is suffered by adults probably as a result of the large amount of time spent searching for

food on the ground where they can easily fall prey to a cat.

Snow and Mayer-Gross (1967) have tentatively proposed the following generalisation on suburban songbirds:

> . . . more young are produced per pair in proportion as the habitat has been altered by man from the primitive woodland condition towards the tamed suburban condition and . . . this is so because nest predation declines and in spite of the fact that feeding conditions become less good.

Thus if the blackbird, which has been the most studied, is typical it would appear that many suburban areas provide a surplus of individuals which may either disperse and colonise new areas of the built-up districts or return to more rural areas where lower densities pertain.

2.3.5.6. Other Birds Found in Urban Areas

There have been fewer studies of birds which originally derived from habitat other than woodland. Birds typical of open grassland are poorly represented in the built up area as are marshland species. Cliff-dwelling species such as the feral pigeon are known to be prolific and this is the outcome of breeding almost year round in response to elevated temperatures and a plentiful food supply. The unique study of the peregrine falcon in Montreal indicated that this species can also enjoy heightened success when raising young in the urban environment (Hall, 1970). Hickey (1970) reported an average success rate of 1.1 fledglings per nest site in natural mountainous habitat which can be compared to Hall's figures of 2.2 per nest over the period 1940 to 1952.

2.3.6. Conclusions

The environment in urban areas differs from that found in the surrounding countryside and thus offers a competitive advantage to some species while causing the exclusion of others. The species composition of wild fauna changes as human population density increases although the total number of animals in an area may not alter greatly and indeed can increase for some species.

The urban species which are most numerous possess a great flexibility of behaviour allowing them to exploit new resources. In particular they display an ability to tolerate the presence of man and his perturbing activities.

There has been very little scientific study of plant physiology or ecology in urban areas and it is not clear whether any special characteristics exist. It would seem likely that many ecotypes might have evolved to exploit the variety of site conditions to be found in cities.

It is evident from this collection of information that there are many interesting problems worthy of serious study in view of their involvement in an ecosystem which man has principally created. Wildlife as a pollution indicator may yet prove to be, at least in the short term, a motivating force bringing about an increased interest in the subject of urban ecology.

CHAPTER III

LONDON: A CITY WHERE WILDLIFE HABITAT IS AN INTEGRAL PART OF THE URBAN ENVIRONMENT

Since 1858 London has had an active natural history society (LNHS) to record its many species of indigenous and exotic flora and fauna. Until recently the emphasis has been on identification and accumulation of species numbers but ecological studies have emerged in the past decade. Table 3.1 has been compiled from LNHS annual reports for the years 1960-1970 and provides evidence of the viability of metropolitan London as a 'wildlife' area.

An interesting point of speculation is that many cities may be equally well endowed with a variety of plant and animal species but due to a lack of urban naturalists, little documentation exists and thus the true diversity of the city is unknown to most of its residents.

3.1. Natural History of London

It will be apparent from Table 3.1 that a rich variety of species persists in the metropolis along with its eight million human residents. That some animals have been less able to remain than others is shown by the relatively few carnivorous species recorded. Only the smaller carnivores are tolerated and in Britain as a whole very few of

Table 3.1. - Flora and Fauna of the London Area*, 1960-1970, as Recorded by the London Natural History Society (LNHS)

Type	No. of Species Seen in London	Seen in UK	Per Cent of UK Species Present in London
Terrestrial Mammals	32	52	62
Insectivora	5	6	83
Chiroptera	10	15	66
Carnivora	4	11	36
Artiodactyla	3	9	33
Lagomorpha	2	3	66
Rodentia	8	17	47
Reptiles	6	10	60
Amphibians	8	12	66
Fishes	33	45**	73
Birds	203	301	66
Invertebrates			
Macro-Lepidoptera	728		78
Hemiptera-Homoptera	317		82
Diptera	2,300	5,200	44
Coleoptera	248	3,700	7
Plants	1,835	c.3,000	61

*The London area is described as that contained in a circle of radius twenty miles from the St. Paul's Cathedral, approx. 1200 mile^2.

**Only fresh and brackish water fishes.

Compiled from LNHS reports 1960 - 1970.

(Other sources of data - Fitter, 1963; Southern, 1964).

the indigenous species of carnivore still remain (Southern, 1964). By contrast, herbivores, even the larger ones such as deer, are still to be found in cities although they are not truly wild. Three semi-wild herds exist in London, one is kept at the Royal Park in Richmond, another at Bushy Park, and the third thrives in Epping Forest (Hurcomb, 1969).

Smaller animals, particularly invertebrates, survive in large numbers wherever suitable habitat has been retained or created. A good example of a relatively undisturbed area which supports an incredibly varied plant and insect population is the garden of Buckingham Palace (McClintock, 1964; de Worms, 1965). Some fourteen per cent of all Lepidopteran species found in the British Isles have been reported from this central oasis.

Resident birds are the most apparent of all city animals and Fitter (1945) listed fourteen species which he termed the "garden association" being those most successfully adapted to living with man. As a result of its location, London also serves as an important staging area for migrants passing through in spring and autumn (Lond. Bird Rep., 1963, 27:5). Certain of the central London parks regularly report unusual species in times of bad weather conditions on the Continent (Min. Bldg. and Pub. Works, 1970). There are few raptors in the resident avian population but the kestrel is still found in the inner districts and tawny owls thrive wherever they can find adequate nesting and roosting sites

(Brown, 1963; Montier, 1968).

Plants are to be found everywhere; many are introduced ornamentals but a wide selection of the so-called weeds are present in parks, gardens, cemeteries, and on waste ground. With the large bird population and the abundance of seed sources within and surrounding the built area there is unlikely to be a shortage of propagules to exploit any freshly turned soil (Peterken, 1953; Bangerter, 1961).

In order to attempt an understanding of the underlying reasons for the maintenance of such a rich natural element in the metropolitan landscape, it is necessary to select the probable controlling factors and examine them individually. An excellent review of the natural history of London was published in 1945 by Fitter and this together with the aforementioned reports of the LNHS provide the principal information sources.

3.2. Climate

According to Köppen's classification of climate the whole of the British Isles is included in the warm, temperate zone which does not experience a marked rainy season. The climate of the London area has been treated in detail by Chandler (1965). Essential features of the regional climate include a relatively wide range of monthly mean temperatures in the London basin (56°F) mainly as a result of the higher mean summer temperatures when compared to other parts of Britain. Cold winters are a rarity and snow cover is to be

expected on five to ten days in an average year. Rainfall (annual average 21-29 ins.) is distributed throughout the year and thus relatively high humidity persists most of the time. The prevailing winds are from the southwest and in view of the orientation of the Thames valley there results an inefficient dispersion of air pollutants in the low lying industrial areas.

In common with all cities London suffers air pollution problems, the important pollutants being sulphur oxides and smoke. Following the passing of the Clear Air Act of 1954, a number of smokeless fuel districts have been created and tangible improvements in air quality documented. Seasonally high accumulations of pollutants nevertheless continue. Commins and Walker (1967) calculated that over the ten years 1954-1964 smoke concentrations were three times greater in the winter than in summer. Similarly, the SO_2 concentrations were twice as great in winter. According to Chandler (1970) smoke emissions have decreased by 50 per cent and sulphur emissions, while increasing by some 30 per cent, have not produced an increase in the ambient concentration of SO_2 at ground level in the city. Since 1956 the frequency of severe fogs has dropped and an increase in sunshine hours recorded between September and March (1958-1967) is evident in central London (Jenkins, 1969; Chandler, 1970). Thus London has a mild climate which favours a wide variety of both resident and migrant species and recent improvements in

air quality may be expected to further increase its attractiveness as an environment for wildlife.

3.3. Spatial Development

The settlement of London was first established by the Romans around A.D. 50 and in the past nineteen hundred years has grown from an original area of 330 acres (0.52 $mile^2$) to its present 750 $mile^2$. Since 1945 government policy has dictated that growth be restricted and much of the expansion in the region has occurred in the surrounding areas where new towns have been located. The population density of London displays a pattern of concentric rings of decreasing density around the central district. (In the last decade the residential population of the central area has declined markedly but there still remains a large daytime office population.) The urban area extends to a fifteen mile radius beyond which the green belt preserves significant amounts of open countryside. This basic pattern is disrupted by radial developments along major transport arteries. With respect to land use the metropolis can be divided into three principal zones: a central area dominated by high rise office blocks and shops, a belt of three to seven miles extent containing factories and houses built in the eighteenth and nineteenth centuries, and a peripheral belt of suburban twentieth century housing largely of single family, low density type. This outer land-use tends to sporadically penetrate the green belt creating

a juxtaposition of the natural and built environments (Clayton, 1964).

3.4. Vegetation in the London Area

The influence of man is so marked throughout the lowland regions of Britain that it is difficult to distinguish indigenous vegetation. Originally, the clay lands were thickly covered by oak wood (*Quercus* sp.) while the drier chalk uplands supported beech woodland (*Fagus sylvaticus*). Areas with sandy deposits probably harboured a heathland flora but may well have had a scrub oak and birch cover in the undisturbed condition. None of this original cover exists today following the early invasion of the chalk lands for agriculture and the later clearance of the oakwoods (Darby, 1951).

Remnants of mixed woodland dating from the eleventh century may still be found but they tend to be much less dense than the original cover, and are comprised of mature trees scattered among young trees with a rich understorey of shrubs and herbaceous species (Peterken, 1953).

Aquatic vegetation can still be found in rivers, docks and in ornamental lakes or pools such as those which adorn many city parks. Little remains, however, of the extensive marsh and bog vegetation which formed an important component in the pre-Roman landscape.

Turrill (1948) has suggested that few species have been extirpated from the British flora entirely as a consequence of human activities but many aliens have been

introduced. Some of these exotic species such as elm, larch and sycamore (Acer pseudoplatanus) were intentionally imported for their ornamental qualities but many arrived in consignments of crops and other raw materials. Within the British Isles a great deal of interchange of genetic material has resulted from the carriage of propagules in local building materials exported to urban areas.

3.5. Physiographic Control of Development

Within the Greater London area local relief ranges from 10 to 882 feet above sea level. The primary feature is the Thames basin with its famous river and associated gravel terraces and alluvial floodplain. The predominant direction of flow is from west to east; in the west the river flows through clay, river alluvium and gravels, whereas to the east of the City of London between Dartford and Gravesend it penetrates the chalk outcrop. It is tidal as far as Teddington, with a range of 20 feet near London Bridge.

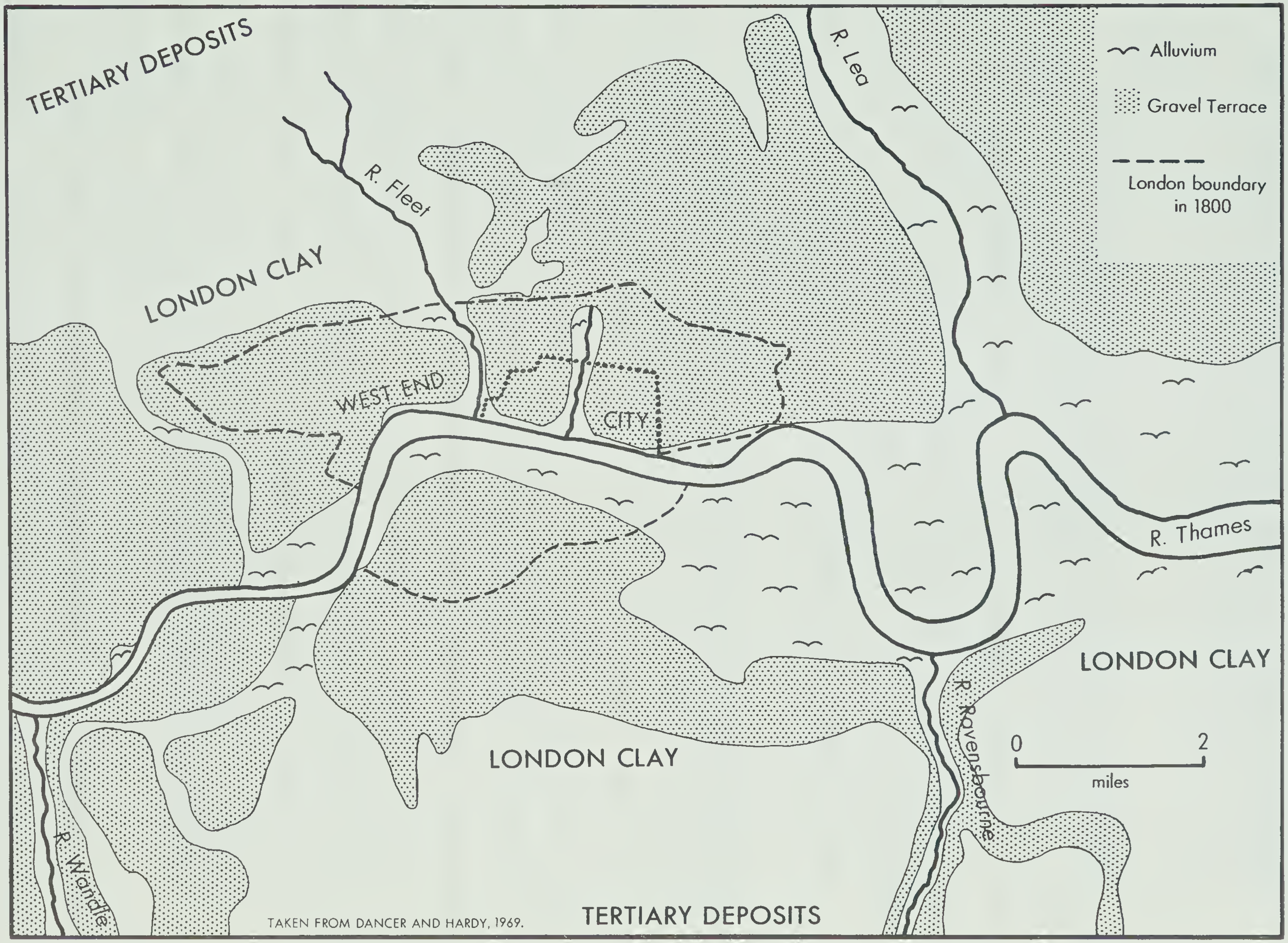
The river valley was the site of the earliest construction with settlement limited to gravel hills, the outline of which may still be detected within central London today. The expansion of building beyond the valley was delayed until the nineteenth century because the extensive London Clay to the north presented an intractable environment to the contemporary technology. Tertiary deposits both to the north and south of the city provided land at higher elevation which became the preferred residential locations of

the rich city merchants in the seventeenth and eighteenth centuries (Clayton, 1964).

Thus London until the start of the nineteenth century was limited to those parts of the region which provided firm foundations, workable soils, easy drainage, and allowed wells to be drilled for drinking water. Marsh land and clay soils remained much as they had been for thousands of years except for some low intensity grazing for dairying purposes. Riverside settlements were prosperous and managed to provide a high standard of living as a result of the excellent fishing available in the Thames and its estuary. The extent of the settled area at that time was small with a population of 900,000. After 1801 the ensuing changes in technology resulted in a quadrupling of this population within eighty years (the population by 1880 was 3,680,000).

The terrestrial wildlife habitat of the region would not have been greatly diminished by the growth prior to the nineteenth century and only central London where air pollution and sanitation problems abounded would have proved inimical to life. However, it is clear that the floral and faunal characteristics of the attractive uplands such as Hampstead Heath or Sydenham Heights would have been modified by the creation of country estates. The agricultural methods tended to produce a very diverse, small scale landscape of fields and hedgerows which would have increased the species diversity in the associated animal community compared to that which

Figure 3.1 Physiographic control of London's growth before 1800



existed in the dense oakwoods. Industry was restricted to some clay workings and brick kilns which no doubt produced local air pollution but added numerous small ponds to the landscape.

The same could not be said for the aquatic habitat which even in the very earliest phases of settlement was subjected to considerable change. Butler (1962) has traced the demise of London's smaller streams and rivers commencing with the covering in of the Wall Brook in 1461 and the subsequent taming of the Langbourne, the Holebourne, the Tyburn, the Fleet and many others.

The growing need for potable water saw the beginning of the gradual fall in the water table which still continues and this has added to the loss of wetland areas. This era of limited, slow modification of the countryside came to an end around the middle of the nineteenth century when the skills developed essentially released the human population from most of the landscape controls exercised upon it prior to this. Thus it was that the wetlands were drained and filled, the steepest hills were cut and levelled to allow building, and sewer systems using earthenware pipes brought about the surrender of the clay lands to the invading suburbs (Clayton, 1964; Dancer and Hardy, 1969).

With man's competitive powers so enhanced the principal means by which wildlife habitat could then be retained in the metropolis was by government regulation.

3.6. London's Development: the Last One Hundred and Fifty Years

The growth in the metropolitan population continued with only a temporary halt occasioned by the First World War. The years 1921-1939 saw the population of London growing at twice the national rate due to urbanisation. By 1961 the city region contained more than thirteen million people and it is projected that the figure in 1981 will be close to sixteen million (Clayton, 1964). As a result of the adoption of the Abercrombie proposal for a Green Belt a substantial proportion of the post-war growth has been in satellite settlements. The intervening land has been left in agricultural or recreational use which has generally favoured the maintenance of wildlife populations (Figure 3.2).

3.6.1. Pollution

An important outcome of the explosive growth in London's population between 1800 and 1940 was the rise in all forms of pollution. The levels were such that Thameside ports were unable to continue commercial fishing and the last salmon was taken in 1833 (Fitter, 1945; Wheeler, 1969). The vegetation was assailed by particulates and sulphurous fumes from the many industrial and domestic furnaces burning soft coal. Although relatively few records were kept there must have been many species which were extirpated from the heavily populated areas (Fitter, 1945; Bangerter, 1961).

While planning legislation enacted in the forties

Figure 3.2

London and the Green Belt

managed to halt the continued peripheral expansion of the built area it was not until the fifties that the first comprehensive attempt was made to control pollution. In 1954 the Clean Air Act created smokeless zones which have been successful in decreasing smoke emissions. The return of both the swift and house martin to the inner London area is believed to be connected to this improvement (Cramp and Gooders, 1967; Gooders, 1968). The Water Resources Act of 1963 has been instrumental in bringing about significant improvements in the quality of Thames water (Marlborough, 1963; Wheeler, 1969, 1970). For illustration, in 1951-1954 a weekly sampling of the water between Putney and Southend showed that contamination was greatest in the summer months resulting in noticeable amounts of hydrogen sulfide (H_2S) emanating from the river. Dissolved oxygen levels were close to zero during such periods from five miles above London Bridge to a point some twenty-seven miles below. However, in 1970 Wheeler was able to report that a total of forty-two species of fish had been recently recorded in the Thames below London, thus providing one indication of the success of the pollution controls. An additional benefit attributed to reduced water pollution has been the presence during recent winters of large flocks of waders and waterfowl on the lower reaches of the Thames up to Woolwich (Grant, 1970).

In general, the obvious forms of pollution have been diminished in the metropolis over the last decade while the

less perceptible forms have grown in number and intensity. The motor vehicle has contributed maximally to this increase; so too has the accumulation of solid waste and the various techniques employed in its disposal. The use of synthetic, persistent compounds has accelerated their dispersal throughout the global ecosystem and they can be assumed to be important factors in the viability of wildlife communities in London (Tarrant and Tatton, 1968).

3.6.2. Habitat Modification

The landscape created by agricultural activity in the past centuries has benefited numerous plant and animal species. Until the 1950s farming had produced a mosaic of small fields separated by hedgerows and lanes with an accompanying profusion of "edge" species. The recent trend to larger field units has resulted in a drastic reduction in the hedgerow habitat to the detriment of the local wildlife populations (Hooper, 1970). The impact of this change has not been too noticeable in the London region except on the eastern edge.

Land which has once been farmed and later abandoned shows a gradual return to a tree dominated vegetation cover. The successional process by which this transition occurs may be observed around the urban area wherever land values reach levels that make development an attractive proposition. In addition to the urban-rural fringe other areas show successional trends in the vegetation cover. Many tracts of

common land which now lie within the London region are no longer grazed by stock and are thus reverting to scrub and potentially to woodland, e.g. Bookham and Ham Commons. Despite the observed release from grazing pressure many of these open spaces now serve as prime recreational areas and their vegetation shows arrested development due to trampling and repeated fires (Lond. Nat., 1962, 41:23; and 1965, 44:126).

The impact of increased human numbers on a slowly decreasing amount of open space has meant a reduction in the usefulness of this acreage as wildlife habitat. Carrying capacity is affected when increasing areas are turned over to lawn and sports ground; dogs and children trample peripheral vegetation and use of these spaces extends throughout the year.

The advent of the automobile in the early twentieth century has had its effect through loss of habitat, increased pollutants, and as an instrument of death for small birds, insects and mammals. Despite the acknowledged importance and uniqueness of the Royal parks which grace the central area not even these are inviolate when the needs of the car are to be satisfied. Hyde Park in addition to many other parks and commons has lost acreage in the race for extra parking space and highway extension to alleviate traffic congestion.

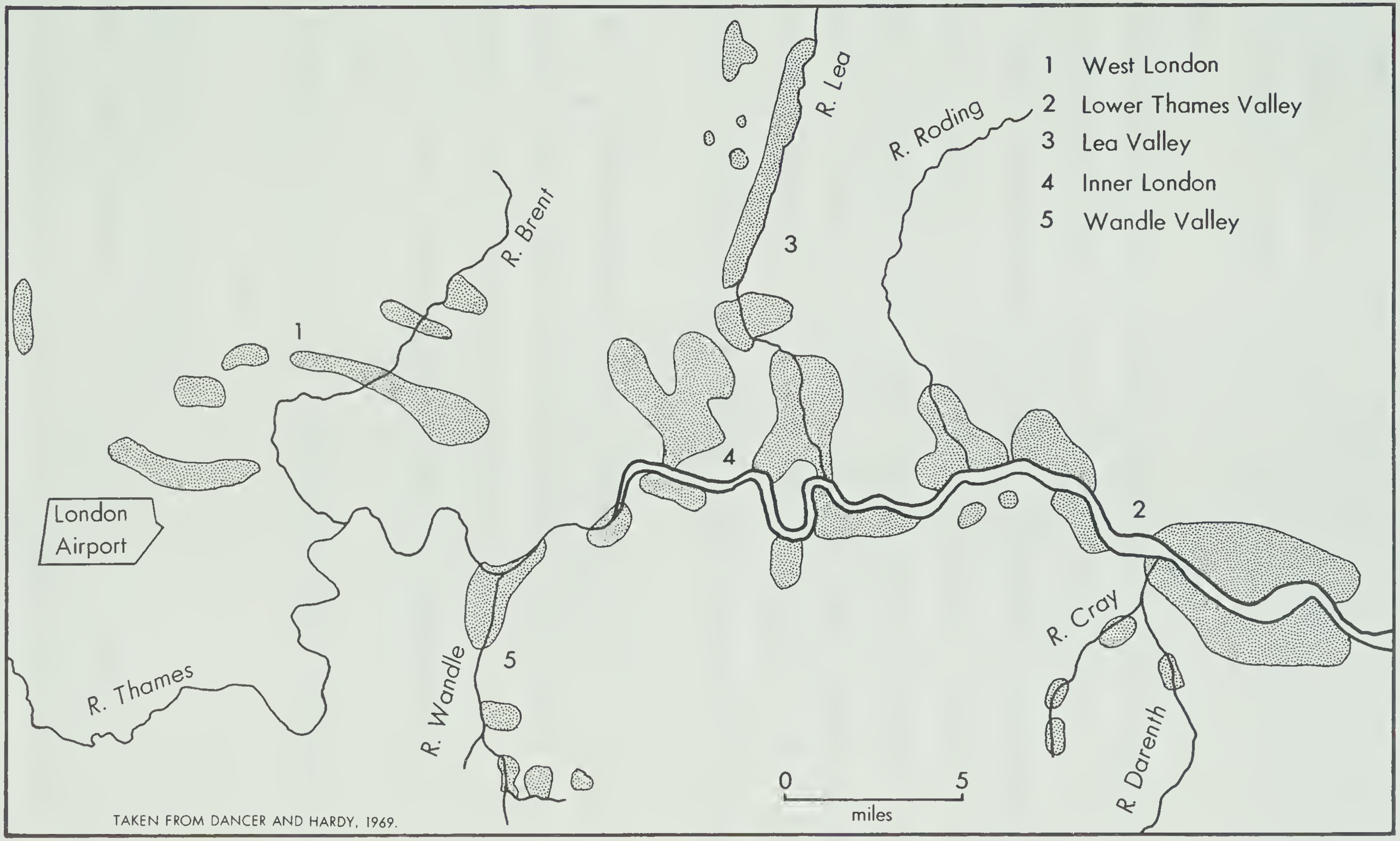
One consequence of all the construction has been the extensive excavation of building materials such as limestone, sand, gravel, and clay. Initially such activity means

destruction of plant and animal communities but following completion of the extraction a new habitat is left which can be very valuable. Unfortunately many of the pits and quarries so created have been used to dump rubbish and other unwanted materials and the land later placed into use for recreation or grazing. Many, however, remain as unused land and can be important oases of wildlife. Chalk pits in the south and east sections of the London region for example are known to be very rich botanical sites (Peterken, 1953; Lond. Nat., 1967, 46:24-25).

For many years one of the most economical methods of garbage disposal has been the filling of marsh along the Thames valley with the consequence that this habitat is almost non-existent today (Figure 3.3). In its place are docks, warehouses, playing fields, and industrial estates. This distinctive element of the ecosystem is therefore very rare in the London area today and is relegated to landscape remnants or to man-made structures which replicate to some extent the original conditions. Additional aquatic sites have been provided through the years by the excavation of canals, reservoirs, gravel and clay pits. Gravel pits are often in flood plains and thus become man-made lakes which can simulate natural conditions attractive to waterfowl and small mammals (Glue, 1970; Harrison, 1970).

One other loss occasioned by the growth in the number of single-family dwellings is the demand for turf to

Figure 3.3 Concentration of industrial areas along rivers



give the innumerable small gardens their most characteristic feature. Some of the commons (Hampstead Heath, Mitcham and Wimbledon Common) have suffered very badly from these deprivations, losing turf, sand, gravel, and peat in the face of development.

The original housing developments in the countryside around the City of London took the form of mansions set in either parkland or woodland hunting preserves. Following the era of suburban sprawl in the early twentieth century, these estates were surrounded and many succumbed to multiple housing development schemes. A small number were acquired by far-sighted municipalities who saw their amenity value and their potential use as 'green lungs' for the densely populated districts.

Where these estates were broken up their loss had marked effects upon local wildlife populations since such areas provided a high capacity woodland habitat which acted as a reservoir from which migrants could colonise less viable wildlife areas.

A summary of the major influences upon London's wildlife is provided in Table 3.2.

3.6.3. World War II, 1939-1945

Before discussing the viability of London as a centre for wildlife populations it must be recorded that during the Second World War a macabre experiment in habitat manipulation

Table 3.2. - Activities and Changes in Land Use Which Affect Wildlife in London

Construction	Extraction of building materials Erosion, sediments carried to watercourses Source of air pollution Alteration in percolation and run-off
Flood control and drainage	Change in water table Succession to terrestrial ecosystem Alternative use in agriculture or housing
Waste disposal	Filling of marshland Filling of quarries and pits Sludge dumped into watercourses Effluents discharged
Recreation	Trampling of vegetation Soil erosion Disturbance of animals Killing certain species Collecting specimens Feeding certain species
Conservation	Ecological surveys Management of green space Supply of nest boxes Creation of sanctuaries

was enacted. The influence of the London Blitz upon the human population is well known but it had some equally pronounced effects upon plants and animals of the area (Fitter, 1945).

In the days between September 1940 and May 1941 something of the order of one-third of the old City of London was devastated and in subsequent years other areas of the metropolis suffered extensive damage. The outcome of these sudden changes in the environment was the provision of a diversity of small spaces comprising a mixture of rubble piles, ruined structures and freshly turned soil. The resilience of natural plant populations was amply demonstrated by the positive riot of annual species which soon colonised the bombed sites. A survey conducted during this period revealed a total of twenty-seven plant species in 1942 on the sites but this count rose to one hundred and twenty-six in the years immediately following cessation of hostilities (Salisbury, 1943). The species involved were typical of pioneer communities distinguished by their ability to germinate and grow rapidly so as to take advantage of transient and disturbed conditions. Where the sites received no further damage normal succession occurred with the result that a shrub community developed (Parmenter, 1968). Thus it was that earth which had been built over for thousands of years was productive and capable of furnishing wildlife habitat within a few months of being once again exposed.

An additional feature of wartime London was the

omnipresent, static water tank, and these together with the scattered pieces of meadow and scrub-type land allowed a gradual colonisation by animals. Yet another aspect of importance in explaining the biological invasion which occurred was the number of domestic gardens which through neglect became the equivalent of reserves or sanctuaries.

Ruined buildings furnished a variety of nesting and roosting sites which were taken advantage of by birds, insects, and rodents. It is likely that other mammals may have been in evidence but it should be recalled that during this period few naturalists had free time and much evidence that might have been available was never recorded. A notable species that exploited the bombed sites was the black redstart. This bird had not been recorded as a breeding species in central London before 1940. The first broods were reared in the precincts of Westminster Abbey and by the year 1949 the tally in the central area had reached fourteen pairs all successfully feeding on the insects which associated with the herbaceous ground cover. No doubt they also benefited from the presence of the aforementioned water tanks which must have been a rich source of flying insects in the warmer months of the year. Other birds enjoyed this newly provided resource area and it was reported that migrant warblers were to be seen searching the foliage on the older bombed sites where elder (Sambucus nigra) and willow florished.

With regard to wildlife there was a debit side insofar as some acreage in the larger parks was ploughed and

turned over to crop production. There was also some felling of commercial quality timber in the London area but the more valuable trees as far as wildlife needs were concerned, were over-mature and hence not attractive to the forester. All other evidence suggests that there was an appreciable increase in natural vegetation and reduced intrusion and disturbance by people. While such devastation as was witnessed in London at this time cannot be recommended, it was instructive in revealing the capacity for other organisms to colonise previously built up areas.

To a lesser degree this same process was apparent in the early sixties when underpass construction and highway schemes in Hyde Park produced spoil-heaps and fresh expanses of earth. Several observers reported a bewildering array of annual grasses and weedy species, noting particularly the occurrence of alien grasses. This was a new development not apparent during the wartime plant invasion. The source of such grasses is believed to be bird seed which in recent years has been continually scattered by people feeding wild birds. Undoubtedly many seeds are also disposed of into garbage bins and ultimately these reach open dumps where they may be transported by wind or in the gut of scavenging birds (Lond. Nat., 1962, 41:13; 1963, 42:11; 1967, 46:26).

3.7. Green Space and Wildlife Habitat in London

Within the metropolis a great deal of unbuilt land has been retained and this serves a variety of functions

including provision of wildlife habitat. Table 3.3 lists the principal types of land use and the form of natural habitat which they provide.

Table 3.3. - City Habitats

Natural Habitat Type	Urban Land Use	
Wetland	Gravel pits Sewage farms	
Aquatic	Sewage farms Water tanks Reservoirs Gravel, clay pits Ponds and lakes in parks/gardens Watercress farms	
Open - grassland	Airports Playing fields School grounds Roadside verges Public parks	Common land Railway banks Canal banks Race courses
- arable	Gardens Agricultural and horticultural land	
Parkland	Institutional grounds - hospitals, prisons Public parks Cemeteries Golf courses Common land	
Woodland edge	Hedgerow Schools Institutional grounds Garden shrubberies Churchyards Golf courses	
Cliff and ravine	Chalk pits Quarries Walls Bridges Viaducts and aquaducts Railway cuttings	

In view of the statement made earlier concerning the

lifting of restraints upon development during the nineteenth century it is important to consider by what mechanism the present day green space has been retained. Unfortunately it appears that most of this land has been saved by accident rather than as a result of far-sighted planning by the city fathers (Map showing green space, London, Appendix D).

3.7.1. Public Open Space

Parks in London are the property of the Crown, the Corporation of London, or the Greater London Council; the latter two bodies also own common land and other open spaces in the metropolitan region. The total land involved is of the order of 28-29,000 acres.* Not all of this is open or green nor is it wildlife habitat since this total includes land upon which houses, hospitals, offices, and libraries stand, also areas such as sports grounds, golf courses, and stadia. Such land is nevertheless useful as a feeding ground for birds by day and may serve a similar function for nocturnal mammals. When it is realised that many of these areas are linked to one another or to a corridor of some kind it becomes apparent that much of the acreage is able to support some wild species. The critical areas are those with good ground cover and mixed shrub and tree communities which can act as reservoirs to supply the less optimal locations with replacement organisms.

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*When added to the land area contained within the Green Belt a total of 40,000 acres is set aside as permanent green space for public use.

The principal central London parks have their origins in the medieval period when they were set aside as Royal hunting preserves or sites for country palaces. Over the years the people gradually acquired the right of access to these "noble playgrounds". In the mid-nineteenth century a 'parks movement' blossomed and resulted in local government agencies acquiring large private estates and derelict land within their administrative areas for conversion to public parks or institutional use (Church, 1956; Chadwick, 1965; Trent, 1965; Jellicoe, 1970).

The parks which were designed for the people of London in the 1800s were very formal and paid no attention to their potential use by wild species. Regent's Park for example, was principally established to provide an elegant pastoral setting for many fine town residences and the so-called 'natural' elements in the landscape consisted of stylised plantings of exotic shrubs and trees, as well as artistically pleasing ornamental flower beds and lakes, the whole offset by much decorative ironwork, ornate architecture, and numerous statues. It has only been in recent times that a maturity and naturalness has invaded these nineteenth century parks making them very attractive to a wide variety of birds and a few mammals (Chadwick, 1965).

One other very characteristic form of green space which enhances the image of London is the delightful squares which date from the seventeenth, eighteenth, and nineteenth

centuries. Some still remain enclosed with keys available only to residents of the square while others such as Soho and Berkeley provide welcome resting places for walkers, residents, and office workers alike. With respect to wildlife management they hold an aesthetic rather than a practical appeal since few species can exploit these small areas. Reports of wood pigeons, crows and even magpies nesting in the plane (*Platanus acerifolia*) trees of London squares are known.

The other important source of metropolitan open space is the peculiarly British feature known as a 'common'. Such land was the common pasturage of the peripheral villages which existed prior to the nineteenth century explosion of London's urban populace.

Stamp (1969) has described the importance of common-land for its amenity value and noted that these acres are in fact privately owned but as a result of an Act passed in 1886 they may never be enclosed. The public therefore has no general right of access but the custom of years has in many instances established a 'de facto' right of entry. The majority of the commonland within the London area is now in the hands of local government and thus becomes legally open for public use. This has unfortunately added to the likelihood that such land can be swallowed by highway construction as in many cases the owner of the land and the highway builder are one and the same authority.

It is obvious that the presence of these major pieces

of countryside which were subsequently to be locked in the urban fabric, must have been significant factors determining the location of high class residences in the past. The usefulness to wildlife of such parks as Richmond or the area of Clapham Common was greatly increased by the erection of large houses with spacious grounds adjacent to their boundaries. The continued expansion of London and the rise in land prices has already brought about the demise of many such elegant properties. Some have merely been converted to flats but others have been demolished and replaced by apartment blocks. The result is similar in that the grounds are fragmented and much of the land disappears under concrete and asphalt to provide car parking space to meet the needs of the greatly enlarged human population.

One fortunate outcome of the historical derivation of central London's green space lies in its location. Most of the major parks and commons are elevated above their surroundings standing as they do on tertiary deposits. Such sites are favoured by decreased air pollution levels due to stronger winds, increased precipitation, and greater sunshine (Chandler, 1965).

3.7.2. Open Space Network

Thus it appears that the verdant aspect of Greater London may be accounted for by the indulgent tastes of medieval monarchs, together with the actions of philanthropists

who in sympathy with the few far-sighted planners started battling to retain greenery during the first decades of the nineteenth century. In a few cases the banding together of private citizens to purchase land by subscription has secured important natural areas.

The result of utilising such a haphazard mechanism is the present abundance of isolated units scattered throughout the urban fabric. There is no obvious open space network as may be detected in say Cleveland, or in Stockholm where definite plans of land acquisition were followed (Tunnard and Pushkarev, 1963). Despite this fact it is obvious that there are functional wildlife corridors between many of London's open spaces. This linkage is effected by the variety of transportation routes throughout the metropolis (Figure 3.4). The general pattern of railways is a radial one and so too is the older road system which has been extended in the motoring age to include an orbital component. This linkage system allows the possibility of migration between rural wildlife populations and those in the enclosed natural spaces.

This transportation net was built up over a long period of time commencing with the mud carriageways of the pre-industrial era, moving through the canal age (1800-1830), the railway boom, (1840 onwards) and culminated in the Underground system of the 1930s and the contemporary road system. In addition there are many pedestrian and equestrian pathways in the suburban areas dating from the previous century.

Figure 3.4 Wildlife corridors formed by surface railways and streams

The utilisation of such corridors has been mentioned in connection with the dispersal of animals but they can also provide permanent habitat for some plant and animal species. For example, in chalky areas railway cuttings are known to carry a diverse herbaceous cover and may harbour a few plant rarities. They are therefore attractive to insects and can in the instances where the soil is sandy provide well drained sites for fox earths and even rabbit warrens (Lond. Nat., 1963, 42:12; 1964, 43:135).

3.7.3. Undeveloped land in the Metropolis

Many landowners develop only a small proportion of their total acreage and much remains in some form of biologically productive state. It is possible to consider three major categories of urban land use in this connection; one may be termed institutional, another utilities, and the third domestic - commercial; these are illustrated in Table 3.4. It is often the case that institutional land abuts major open space and this is an extremely important factor helping to maintain the viability of the public open space as useful natural habitat (Gooders, 1965).

It would appear that one of the most productive utilities is the sewage farm and its rich plant and animal life have been ably documented by Jones (1961), Gladwin (1963), and Parr (1963), but technological change threatens to reduce the extent of this land use. The old type of sewage farm is being rapidly replaced with the more compact, enclosed

purification works which is much less attractive to both resident and migratory species (Lond. Nat., 1966, 45:8).

Table 3.4. - Undeveloped Land in the Urban Area

Institutional	Utilities	Domestic-Commercial
University-Colleges	Sewage farms	Gardens (Backyards)
Schools	Reservoirs	Market Gardens
Hospitals	Canals	Industrial Estates
Prisons	Gravel Workings	
Nature Reserves	Airports	
Clubs	Churchyards	
Corporations	Cemeteries	
Municipal Offices	Rights-of-way	
Golf Clubs		
Race Courses		
Zoological Gardens		

3.8. Viability of Some Animal Species in London

It is clear from the comments made in Chapter II that the success of animals in the urban environment is determined by such factors as behavioural plasticity and the degree of conflict which arises with man as a result of their day to day activities. There may also be effects upon wild populations exposed to the pollutants commonly found in urban areas which render some species more competitive than others.

The differences displayed between the fox and badger in their adjustment to the expansion of London into the rural landscape illustrate this well. Teagle (1967, 1969) has written on the suburban ecology of both species and it is

apparent that the fox has proved more successful in maintaining its status and invading the urban area, and has breeding locations as close as four miles from St. Paul's Cathedral. It is found in proximity to densely populated districts making use of sheds and dumps to provide shelter for the rearing of cubs. It is indifferent to both traffic and noise, and manages to thrive under what at first might appear to be unpromising conditions. Despite the fact that the animal may suffer from the effects of air and water pollution it is less persecuted by man when living in the city and its life is therefore potentially longer. By contrast the badger usually loses the battle with the developers, being repeatedly forced to abandon its ancient setts and retreat to greener acres. One principle difference between the two animals is the greater control exercised upon the badger by the natural physiography of its environment. Unlike the fox a badger normally excavates its own sett and seems unable to live above ground permanently. It is therefore limited by the surface geology of the London region and cannot exploit the whole area. In common with the fox, the suburban badger suffers less direct harassment than his rural relatives because he is not seen as a major threat to crops and livestock. However, his massive excavations when conducted in the relatively small space of a suburban garden can try the patience of even the most ardent animal lover and this has been the principal cause for the badger's retreat to the large open spaces and remanent woodlands.

This matter of environmental limitation will apply to some extent to all creatures for whom burrowing is an essential part of their existence. Moles, shrews, voles, rabbits and birds such as sand martins or kingfishers (Alcedo atthis) will be controlled by the distribution of surface deposits and soil types.

The problem of conflict with man is exemplified by the mole which can cause tremendous losses in the flower and vegetable garden and wreak havoc to sports grounds and lawns. This insectivore spends its active hours burrowing through the soil in search of its favourite prey, the earthworm. Few gardeners or groundsmen are prepared to entertain such a visitor and the mole is trapped and gassed with great persistence. The result of the confrontation is the expulsion of the species from the developed area and its concentration in woodland copses, on commons, or in nature reserves. Again this example can be contrasted with that of another insectivore, the hedgehog which rarely comes into direct conflict with man. It will be recalled however that while man does not regard this animal with animosity, this species suffers great losses on the roads. Despite such high mortality the records of the LNHS indicate that the hedgehog is probably the most widely distributed mammal in the London area. It is found in all the principal parks and seems to thrive in the small gardens even where they are surrounded by high density development. As long as wildlife corridors remain to allow the

species to move when renewal activity occurs and to recolonise the area once building activity ceases, this species will probably persist as an urban mammal.

There is one other small mammal which has invaded London and indeed is listed as a pest in England, and that is the imported grey squirrel. It is possible that its aboreal habit has provided the key to success and its ability to utilise a variety of foods has further aided it.

The lack of representatives from the Amphibia and Reptilia is expected in view of the loss of wetland and aquatic habitat; it has yet to be explained in what way the artificial pools fall short of the requirements of these species. The common frog has become locally scarce and this may result from a combination of circumstances, as discussed in Chapter II.

Without the benefit of specific studies it may be premature to conclude that omnivores with flexible habitat requirements are the most prominent wild mammals to be found in the built up districts of the urban area. However, it should be noted that the fox, hedgehog, and squirrel fall into such a category.

3.9. Factors Controlling the Distribution of Animals in London

A consideration of the LNHS distribution maps for mammals recorded in the London area reveals the fact that only a very few species can survive when restricted to the domestic

garden zone. Most species are heavily dependent upon access to large open spaces with wild vegetation and other sanctuary areas and it is obvious that the largest populations exist in the urban rural fringe zone (Table 3.5).

Table 3.5. - London Mammals - Habitat Use

Mammals	Preferred Habitat
Mole (*Talpa europaea*) Stoat (*Mustela erminea*) Weasel (*Mustela nivalis*) Badger (*Meles meles*) Hare (*Lepus europaeus*) Rabbit (*Oryctolagus cuniculus*)	Peripheral distribution Urban-rural fringe
Mole (*Talpa europaea*) Fox (*Vulpes vulpes*) Squirrel (*Sciurus carolinensis*) Voles (*Microtus* and *Clethrionomys* sp.) Mice (*Mus musculus* and *Micromys minutus*)	Large open spaces throughout the built up area
Hedgehog (*Erinaceus europaeus*) Shrews (*Sorex* sp.) Squirrel (*Sciurus carolinensis*)	Small gardens, hedgerows and parks throughout the built up area

Teagle(1967) believes that the distribution within this zone relates to the kind of topography which prevails on the periphery of the metropolis. Thus he comments:

> The eastern Surrey fringe of London represents a curious picture with glacier-like suburban flows filling long valleys between hills which have retained their woods and chalk grassland.

Inspection of Figure 3.5 reveals a high concentration of mammal observations in the area mentioned by Teagle with a noticeable difference in the eastern and northeastern part of the metropolitan fringe where the land is relatively flat

Figure 3.5 Distribution of mammal observations in the LNHS area, 1956-1969

Compiled from observations on 8 species; Badger, Common Shrew, Fox, Hare, Hedgehog, Mole, Stoat and Weasel.

and therefore almost completely built over.

In view of this conclusion the necessity of maintaining the green belt is paramount if retention of wild populations is regarded as a desirable objective. Mere preservation of existing land will not suffice. It will be necessary to practice ecologically-based land management and take the opportunity of creating new open space and wildlife habitat when renewal schemes are first designed.

It was pointed out that transportation modes have changed through the years and produced an intricate web in which the green spaces lie. New roadway construction is taking place throughout the Greater London area and it is imperative that functional wildlife corridors in London be maintained or new ones created so as not to make the smaller green spaces incapable of supporting stable populations. As yet we do not understand to what extent urban wildlife populations interact with rural ones, or whether there actually may be suburban areas that support a greater number of breeding pairs thus creating a surplus population to migrate to more rural districts.

One further constraint which may yet limit the richness of London's wildlife is environmental contamination, the true extent of which is yet to be assessed. The fact that the most suitable parks occur in the elevated and therefore less polluted districts has already been pointed out. However, these same parks are increasingly used to

provide short cuts for congested, rush-hour traffic and these are a source of hazardous compounds. Parking of vehicles in central parks is a practice which has recently been adopted and must have pronounced effects upon the quality of water seeping into roadside soils. Another perhaps less important problem is that of complaints from vehicle owners who find their cars bespattered with bird excreta or aphid 'honeydew'. Provided that this does not lead to removal of the offending fauna and trees, the use of these beautiful oases as daytime car dormitories may not be particularly detrimental.

One thing which is very evident from the survey of reports in the London area is the great disparity between birds and mammals in terms of utilisation of the urban environment. The mobility of birds allows the exploitation of transient or temporary vegetation and they can survive by using a combination of non-contiguous green spaces, provided they are not too widely separated. Such a strategy is not without danger as was shown by Snow (1958) when he noted the high mortality suffered by blackbirds who fed in parkland across the road from a garden in which they nested. Many a nest was left untended because a heavily laden parent bird collided with a vehicle on its return journey across the highway.

The import of the above observation is evident; wildlife corridors are essential if mammals and other cursorial species are to be retained as components of stable

ecosystems. The word "stable" is most important when considering enhancement of animal populations in cities. We have seen too many instances of unstable systems where one species reaches disproportionate numbers and is rightly deemed a pest. London provides a clear example of the correctness of the belief that stability is associated with diversity of habitat type, vegetation structure, and species. It is equally obvious that the essential requirement in cities is a well planned management program to maintain habitat and create or modify it as required in the face of consumptive land uses.

3.10. Londoners - The Cult of Nature

When discussing the factors which have influenced the apparent success of nature in the metropolis it is necessary to consider the attitudes of its human residents. Fitter (1945) talked of the generally favourable attitude towards certain segments of nature witnessed among the residents of London but indicated that human attitudes toward other living organisms tend to be ambivalent. Fowles (1970) believes that the English people possess a peculiar rapport with their surroundings and that this is exemplified by their passion for gardening and pet keeping. Many people are interested in natural history and are therefore less likely to designate all insects as "bugs" and then adopt a reflex response to spray anything which vaguely resembles a "bug". Clearly this is an interesting and important part of the subject but it requires to be tackled on a scientific basis so as to

allow statements which may be substantiated by fact. Whether it is true that contemporary Londoners are more tolerant of their wild neighbours is open to doubt; that they have by accident been handed a rich natural heritage of green space which happens to harbour a diversity of living organisms is demonstrably true.

In a review of the history of London's growth, Trent (1965) has warned of the potential danger to the present Green Belt which being an artificial rampart can be demolished as easily as it was created. Already it is seen to have been breached in its weaker sections where development has trailed along roads and rail lines which cross the "green ring".

Trent's words suggest the potential danger to the non-human populations of the metropolis if their value is not appraised and definite objectives set for their management as an essential component of the rich resource base of London.

CHAPTER IV

PLANNING FOR WILDLIFE IN THE CITY

This chapter is principally concerned with North America because it is felt that the greatest opportunities for urban wildlife management and creation of natural areas exist on this continent. In western Europe for a variety of reasons (but mainly historical ones) nature has been retained in cities to a much greater extent and thus while similar opportunities may exist the need to exploit them is less critical. Also, the pace of development is much accelerated in North America, thus the urgency of the problem is significantly greater.

The examples of planned nature cited here are drawn from both Britain and the United States but there is a noticeable discrepancy between the two countries. In America there has been relatively little research on non-game species whereas in Britain, since the establishment of the Nature Conservancy in 1949, there has been a growing volume of knowledge concerning management of many different ecosystems. Added to this is the expertise of the amateur naturalists who through their County Naturalists' Trusts have accepted responsibility for the management of many nature reserves, areas of special scientific interest, and municipal commons.

4.1. Open Space in the Urban Region

In the United States open space has been the subject of much attention in recent years principally as a consequence of its inequitable distribution in most cities. The contemporary pattern of undeveloped land in the urban matrix has resulted from the economic pressures which typify the free enterprise society. There is a growing literature describing the various methods by which urban land can be secured for public, recreational, and amenity purposes (Clawson, 1962; Mandelker, 1962; Whyte, 1962, 1968; Strong, 1965; Little, 1968; Brooks, 1970; Smith, n.d.).

Tankel (1963) has provided a general definition of the term 'open space'. It is land and water in the urban region not covered by artefacts together with the space and light above them. He sees the principal functions of such space as three-fold; they have beneficial psychological effects upon those who enjoy access to them and in addition help to shape urban development. Ironically, the third and apparently most important function has been the least appreciated, namely the capacity of open space to protect natural landscape features which are essential contributors to the ecological stability of the region (Goodman and Freund, 1968). Concern for urban open space has been heavily oriented toward its recreational function with little or no recognition of amenity aspects (Mann, 1970).

4.1.1. <u>Open Space Planning</u>

Traditionally this form of planning has utilised arbitrary space standards for recreational activities based upon population density which often bears little relation to the real needs of the urban populace. Land in cities for either amenity or recreational use has repeatedly received a very low position in the priority ratings when resolution of land-use conflicts has been attempted. Inevitably there has been a tremendous loss of green space under bricks and concrete, despite the lowering of environmental quality which this entails (Tunnard and Pushkarev, 1963; Dickinson, 1966; Clawson, 1969). In Britain the "green belt" concept was implemented in the 1940s and its effects upon the London metropolis were noted in the previous chapter. This planning device succeeded to a large extent in counteracting the inexorable sprawl from the city centre but it was a negative rather than a positive tool.

4.1.2. <u>A Holistic Approach to Land Use Planning</u>

Newly emerging concepts may mean that the day is fast approaching when open space will be accorded high priority in land use conflicts (Farness, 1966; Hansen, 1967; Zisman <u>et</u> <u>al</u>. 1968). Davis (1967a) has captured the essence of the new ethic in this branch of resource planning when he states that "open space is <u>not</u> land left over". Indeed, land is a fixed resource and must therefore be treated with consideration for future needs as well as those perceived by the current

generation. A growing number of planners display an awareness of the need to plan all resources as part of an interdependent system. The principle that there is a "best" use for any given piece of land, specified by its inherent qualities, is now seen as the fundamental determinant of land-use planning. Cast aside is the notion that the allocating mechanisms of the market economy which have relied solely upon monetary values, can bring about equitable distribution of resources (Niering, 1960, 1968; Whyte, 1962, 1964, 1968; Tankel, 1963; Downes, 1965; McHarg, 1966, 1969; Dasmann, 1966; Benthem, 1968; Hackett, 1969; Gottman, 1970).

Acceptance of this principle implies a regional or national perspective and ultimately a global approach to resource planning since the contemporary boundaries have been fixed without benefit of these ideas. It also requires that the artificial division between so-called urban and rural planning be removed since the many social and environmental problems which confront society today clearly indicate the shortcomings of the present institutional arrangements. A systems approach based upon a desire to see the whole rather than the parts is necessary if we are to attempt to understand and seek solutions to pressing contemporary crises (Caldwell, 1966; Woodbury, 1966; Davis, 1967a).

4.1.3. Open Space - The Future

Wingo (1963) foresees an increase in the amount of

urban undeveloped land in North America due to the greatly dispersed pattern of urban settlement to be expected in the future. In his words the pattern will comprise "a loosely knit, weakly centred, low-density urban region spread over a wide hinterland". It is essential that such trends be combined with appropriate planning if environmental quality is to be maintained. Already on both the American and European continents conventional, rigorously applied low-density standards are disappearing in favour of the idea of totally planned communities where clustering allows high density building in conjunction with extensive open land as an integral part of the community. A regional plan should therefore inventory all undeveloped land within its physiographically determined region, and ascertain those parcels which by their inherent qualities should be designated permanent open space (McHarg, 1969).

If it is possible to incorporate cluster development into this regional plan such that all green space becomes linked by natural corridors the usefulness of this land will be immeasurably enhanced.

The attractiveness of such rational land use planning is emphasised by some calculations made by Zisman et al. (1968):

> It is estimated that our present rate of urbanisation at (a density of) 30 acres per 100 people would take 10.5 x 10^6 acres to provide for 35 x 10^6 people - that 350 (planned communities) . . . at 100,000 inhabitants each, would consume only 3.5 x 10^6 acres based upon examples of new towns of low density with abundant open space, and would only use 10 acres per 100 people.

In a similar vein, Champion (1970), reviewing densities in British new towns, reported a trend toward an increased amount of urban green space.

In addition to the evident amenity and recreational potential of planned open space networks, another function has been recently highlighted. What might be termed an ecological rationale has been proposed by Odum (1969) and a complementary technological reasoning is advanced by Spilhaus (1971). Their statements focus upon the desirability of creating urban areas interfused with open space linked to the peripheral countryside. Odum proposes a landscape compartmentalised in such a way that a spatial intermixing of variable-age ecosystems is achieved thus providing an overall stability. Such a landscape would appear to fulfill the requirements specified by Spilhaus in order to bring about closure of the many materials cycles whose residuals currently create pollution problems. There is an agreement that we need a coupling of the town and countryside in a form of agro-industrial symbiosis to efficiently utilise and conserve both human and other natural resources (Dickinson, 1966). Others who believe that urban green space is an indispensable element contributing to environmental quality include Safdie (1967), Soulier,(1968), and Ribaut (1970).

4.2. The Opportunity for Planned Wildlife Areas

Shomon (1970) advocates that attention should be paid

to the provision of "open living land" in the city where wildlife would naturally be found. He, in common with Dasmann (1966) expresses the opinion that a city capable of supporting both human and numerous other animal populations will be eminently more "livable" than one which attracts nothing more than sparrows, rats, and pigeons.

If the predictions outlined in 4.1.3 are realised then it is clear that an increasing number of opportunities will emerge for the retention of natural areas prior to development, both inside the city and in the hinterland.

4.2.1. Urban Renewal

Such schemes commonly involve either the removal of several small properties with relatively little attached land or the demolition of a large residence in spacious grounds. In each case it is possible to create excellent songbird habitat. Unfortunately there will often be a limit to the usefulness of these areas due to their isolation from other green areas but the judicious planting of cover and food vegetation will allow some colonisation. Fosberg (1966) believes that an attempt should be made to restore conditions resembling those which existed prior to the original settlement but this idea may be a little unrealistic.

4.2.2. Planned Communities

In both America and Britain the completely planned town is becoming a commonplace and with it lies the opportunity

to establish integrated natural areas adjacent to all buildings (Wilmers, 1971). Whyte (1968) has described in detail the concept of cluster development and the scope which this affords for maintaining areas such as river valleys, marsh, and woodlands.

4.2.3. Industrial Areas

With an increasing emphasis upon service industries and light engineering trades many factory estates are essentially similar to suburban residential areas. As such they could equally well support songbird and small mammal populations.

4.2.4. Institutional Grounds

Such grounds usually do offer considerable protection to wildlife since many are essentially parkland. University campuses have become more dispersed in layout and often present a truly pastoral image. Their use on a seasonal basis aids the cause of wildlife which can find relatively undisturbed conditions during the breeding season. In a similar way hospital grounds are even better in this respect since the degree of intrusion by humans is minor.

Schools have rarely provided very useful wildlife areas due to the small acreage involved, their heavy usage, and a lack of understorey vegetation. Close-cut lawns and mature trees dominate such grounds if indeed, any vegetation is present at all. However, in view of the potential value

of "natural" school grounds for environmental studies it seems important to investigate further the possibilities for increasing the biological diversity of these places.

Zoological and botanical gardens have always harboured wild species in addition to those forming part of their collections. It is possible to devise means of increasing this natural element of both the flora and fauna but investigation would be needed to ensure that no disadvantages accrued, e.g. the transmittal of exotic propagules and pathogens.

Corporate headquarters in the United States are being removed from downtown locations in major cities and re-located in suburban developments. Some of these removals have proffered an opportunity for imaginative landscaping and conservation of wildlife (e.g. American Can Co., Greenwich, Conn.).

4.2.5. City Parks

City parks have traditionally been formal in design with an emphasis upon decorative flower displays, close cropped lawns, and of generally antiseptic appearance. However, the "manicure syndrome" displayed by park administrators may soon be a thing of the past as a result of the recent steep rise in the cost of labour. The decrease in maintenance staff has to some extent been offset by mechanisation but the likelihood of more land being retained or restored to a natural state has grown considerably in the past few years. There is thus scope for imaginative, ecological planning to

produce safe but interesting wild areas which require a minimum of attention.

4.2.6. Derelict Land

Derelict land is often associated with older cities and offers a challenge for the resource planner. Attempts to restore such land have too often resulted in a 'cosmetic' operation producing flat, green expanses suited to agricultural use. It would be better if the land could be evaluated with respect to ameliorating only those factors which inhibit natural re-vegetation thus retaining any topographical disparities. The type of land envisaged is that which remains from the operation of extractive industries and perhaps that left following demolition of buildings (Civic Trust, n.d.; Jensen, 1967; Collins, 1970). A report issued in England in 1963 estimated that some 100,000 acres located adjacent to urban centres were suited to reclamation for development or amenity use (Min. H.L.G., 1963).

One other form of surplus land which has perhaps the best potential for conversion to large areas of wildlife habitat is abandoned farmland. As a result of land speculation it is frequently unprofitable for farmers to continue operations once a city extends to neighbouring land. (The mechanisms of the process differ between America and Britain but the results are similar.) A considerable acreage may come into this category and some thought should be devoted to

securing strategically located parcels and protecting them from suburban sprawl. Such land could ideally be turned to use as educational nature reserves where the process of succession could be witnessed at first hand. Furthermore these acres could provide excellent sites upon which to conduct planned experiments in habitat creation.

4.3. Principles for Establishing Natural Areas Which Provide Wildlife Habitat

Certain points must be borne in mind when choosing land for the propagation of wildlife. Three requirements which must be met by any habitat are the provision of cover, food, and water in close proximity (Stearns, 1967).

Inevitably when dealing with urban areas it will rarely be the case that land will be designated for a single purpose; rather it will be expected to perform both a recreational and protective function incidental to its ability to harbour wildlife. However, it should be recognised that there will be a need to establish key areas which are primarily managed for the benefit of the natural populations in order that these areas can function as reservoirs in the region.

4.3.1. Distribution

Location of natural areas in urban centres should be based upon an evaluation of the adjacent land uses. Dependent upon the reasons for establishing the area, steps should be taken to ensure that external forces such as pollution do not adversely affect the natural occupants. If, of course,

the vegetation is being used to reduce particulate pollution or buffer excessive noise then its location will be predetermined (Leonard and Parr, 1970; Smith, 1970b).

A fundamental criterion of open space design, if the objective be conservation of wildlife resources, is the maintenance of physical continuity between the units by such features as river valleys, hedgerows, or footpaths. The number and spatial distribution of vegetated areas will affect their ability to support animal populations. The network of undeveloped land in the urban matrix may be viewed as a system of interacting nodes of activity where a change in the size or function of one centre will influence others. To illustrate this point it could be predicted that an alteration in the type or amount of human use of a natural area would have significant effects upon the flora and fauna, causing perhaps the sudden dispersal of animals to other nodes. Similarly, the contraction of a park, by loss of land for construction, may result in its becoming non-functional as wildlife habitat thus necessitating migration of its wild occupants. It is also evident that any change in the potential for interaction between centres will bring about a concomitant alteration in the viability of those centres. For instance, it is possible to imagine that city parkland in a river valley could be threatened by highway development. The loss of such a corridor could be expected to significantly influence local animal populations if it could be demonstrated that the valley acted

as a means of introducing individuals from rural areas or it acted as a reservoir of breeding animals which then dispersed to gardens and parks in the built up area.

4.3.2. Size

An important issue to be resolved is that of the adequate size of habitat which is necessary to support a self-perpetuating community of species. Unfortunately this is a topic where a critical gap exists in our present understanding of ecosystems. Very few people would wish to make general statements as to the minimum acreage required for any specified habitat type. While this is regrettable it must also be acknowledged that an absolute figure applicable to all situations might be meaningless since the individual nature of a landscape unit in any given district - the relief, climate, vegetation cover, and drainage characteristics, will determine its carrying capacity for wildlife populations. In addition to this, the past and present use of the land will greatly affect this carrying capacity.

Where feasible the boundaries should be delineated with reference to known facts about community interaction and territorial requirements of the animals. Many species depend upon access to two or more habitats during the course of the year and this should be recognised when setting boundaries.

Minimum sizes have been suggested for different habitat types but little data exist to substantiate them. It is

known that waterfowl populations vary in number according to the ratio of perimeter to surface area of water bodies. Miller (1969) believes that the most desirable ponds are from one to five acres in extent whereas Atkinson-Willes (1969) in discussing large lakes and reservoirs, states that 100-150 acres is the size which produces the greatest waterfowl density.

In connection with wetland environment it has been reported that even very small waterbodies can be useful as habitat provided they are grouped together. It is probable that such clustering is applicable to all forms of habitat and should be an important consideration in urban areas where individual size will almost certainly be restricted.

For songbird habitat it may be feasible to manage as little as one-tenth of an acre if this area is planted with a mixture of mature trees, shrubs, and understorey vegetation (Leefe, 1968). This small size will be inadequate however, if isolated plots are established. Williamson (1967) has suggested that vegetated "islands" of one acre are the minimum viable-sized units of woodland.

It may be suggested that the more mature the ecosystem which is desired to be established, the larger the area that will be needed. Thus it is possible to create a small grassland habitat but not an equally small forest since the "edge" effect will essentially preclude the establishment of true forest conditions. The smallest size for any habitat according

to Moore (1962) is that which enables its essential species to sustain a stable population.

4.3.3. Ecological Principles

In the planning of natural areas or in the creation of habitat there are certain principles that should be considered. The underlying assumption is that genetic and structural variety in the natural environment is both desirable and necessary (Westhoff, 1970). In Chapter II it was suggested that diversity in ecosystems is associated with their stability and if the latter is a desirable characteristic then the provision of diversity becomes a paramount objective in designing urban wildlife habitat (Leopold, 1933; Pimlott, 1969). Four manifestations of diversity are recognisable in any ecosystem namely, stratification and niche differentiation, biochemical diversity, species type, and the relative abundance of species (Odum, 1969). Thus the land selected should be capable of supporting a community comprised of indigenous species grouped in natural patterns to provide a maximum stratification. Topographic variation in the landscape will add to the biological richness because of its inherent potential to encompass a selection of different habitats (Webb, 1968).

Very closely connected to the concept of maximising diversity is the ideal of establishing a self-renewing community. Given that biological richness is achieved, then it will be highly probable that a mature ecosystem will develop

provided that external perturbing forces (such as excessive disturbance, intrusion of toxic substances, or changes in the level of the water table) are controlled so as to guard against regression of the system. Introduction of alien species should be avoided wherever possible although this might prove difficult in urban areas where such organisms may be particularly prevalent.

4.3.4. Habitat Creation

Dependent on the objectives and the time span involved, there are two major approaches to the process of creating or restoring habitat. First, it is possible to establish conditions suited to natural colonisation and then wait for normal successional processes to occur over perhaps a hundred years or more. Second, a higher degree of manipulation is used and semi-mature vegetation planted to speed the onset of a tree cover. In an extreme environment the latter approach might be unsuccessful without a very extensive knowledge of local conditions.

One essential component of animal habitat is water and this is very often missing or present in insufficient quantity in cities. The creation of small pools, streams, canals, or marshes could make an otherwise inadequate urban habitat attractive to many small mammals and birds.

Linear habitat can promote biological richness through its capability to provide shelter, food and nesting areas for numerous animals (Odum, 1959). It includes such features as

hedgerows, dry stone walls, roadside verges, railway cuttings, canal banks, stream sides, pond margins, and utility rights-of-way (Graham, 1947; Johnston and Odum, 1956; Niering, 1958; Appleton, 1970; Hooper and Holdgate, 1970).

Ecological studies of abandoned farmland which can provide useful information for wildlife managers in the urban-rural fringe are Beckwith (1941, 1950), Marks (1942), Spooner (1942) and Minckler (1946).

The information dealing with restoration techniques for derelict land and research on the subsequent recolonisation of the land by plants and wildlife includes Croxton (1928), James (1939), Yeager (1941), Tyner et al. (1948), Whyte and Sisam (1949), Limstrom (1953), Heyl (1954), Verts (1957), Holliday et al. (1958), Holliday (1961), Funk (1962), Koller (1962), Coates (1964), Knabe (1965), Weston et al. (1965), Augustine (1966), Crompton (1966), Karr (1968), Antonovics and Bradshaw (1970), Collins (1970), Peters (1970), and Shetron and Duffek (1970).

It appears that we can envisage the creation of a range of habitats representing all successional phases, given a free choice of sites, adequate funds, and access to ecological data collected in the local area. A warning note must be struck in view of the scarcity of the latter; it is essential that very careful thought be given to the exact type of natural system which is desirable to introduce to the city. Particular habitat types are known to exist in various urban

areas and these specific cases should be subjected to study before attempting to create similar features in other cities (Appendix C).

The first essential step in any such planning is the conduct of an ecological inventory before any manipulation is commenced. Fosberg (1966) has warned that a major problem to be expected is the difficulty of knowing whether a complete, viable community has indeed been established. It may often be the absence of one very inconspicuous species such as a micro-organism or a pollinating insect which determines the vital activities of a dominant member of the vegetation and its absence will therefore mean short-lived success for the community. The basic guideline in all habitat creation is a cautious approach based upon small scale, controlled experiments, using locally gained data and a careful assessment of the trends observed.

4.4. Examples of "Planned Nature"

Experience in the planning of natural habitat for non-game species in urban areas is meagre but recently some attention has been directed to the subject. Evidence for the existence of planned wildlife areas has come to light and an assortment of cases is presented but in view of the variability of the information available only a superficial and somewhat uneven treatment is possible. The fundamental principles and working policies employed in each project have been extracted together with any additional information which might

be useful to intending wildlife planners. Examples were selected which illustrate the different opportunities mentioned in 4.2.

4.4.1. <u>The Wascana Waterfowl Park: Preservation of a Remnant Habitat in the City of Regina, Saskatchewan</u>

In the city centre of Regina an example of natural prairie marsh has been secured and now forms a sanctuary for waterfowl and other wetland species. A marsh and lake area of some 360 acres is managed to provide suitable grounds for breeding, feeding and moulting waterfowl. The density of birds is higher than would be expected in the wild condition and due to the lack of harassment they are much more tolerant of human presence which adds significantly to their value as an aesthetic resource.

The location of the lake, near a small power station has meant that open water is present year round making it an attractive location for wildlife (Hochbaum, 1965).

Objectives:

1. Establishment of and increase in bird and other wildlife populations.

2. Retention and development of the area in as natural a condition as possible utilising the associated native flora.

3. Encouragement of public use of the area, to meet recreational, educational and research purposes.

Working Policies:

1. Establishment of zones for various activities.

2. Restriction of research to that which in no way damages or disturbs the natural conditions.

3. Introduction of 'natives only' policy in all planting.

4. Restoration of certain areas to increase their stability, e.g. erosion control, bank grading, provision of loafing areas.

5. Ecological survey of all existing plant communities.

6. Development of techniques to minimise damage sustained due to human visiting, e.g. hedges, water barriers, boardwalks, observation posts, hardtop paths, prohibition of boating on lake.

7. Minimal use of chemicals within the reserve although it appears inevitable that materials will be carried in from outside.

4.4.2. Planned New City Employing the Cluster Concept

The new city of Columbia is being developed in the State of Maryland adjacent to the national capital. In 1969 the Bureau of Sport Fisheries and Wildlife of the United States Department of the Interior was asked to investigate the possibilities of writing a plan to retain wildlife habitat in this development. The area in total covers some 15,000 acres and of this 3,200 acres are to be secured as green space (Larimer, 1969; Wilmers, 1971). Principles of the proposed plan are:

1. An attempt to devise a land use plan, which will avoid the necessity of imposing numerous regulations on people using the area.

2. In view of the inherent richness of bird life in the district it is recommended that mature and overmature forests, under-mowed grassland, fallow fields, bushy hedgerows, and cultivated croplands be perpetuated. Appropriate management practices will need to be carried out.

3. Land use should be planned to allow low-intensity activities to fringe on natural areas, e.g. golf course, university, industrial park, and playing fields.

4. A major problem to be expected is the detrimental effect of intense human use of the area and its impact on fragile communities, and attention should be directed to its solution.

5. Protection and preservation of all permanent streams with strict attention to the need for retaining the riparian vegetation.

Strategies to increase diversity:

1. Creation of clearings in woodland (1/4 - 1/2 acre) and development of bushy "edge" on the borders of woodland and open fields.

2. Creation of at least one water area to provide fishing and facilitate the establishment of a marsh.

Strategies to minimise damage:

1. Vehicular access to watercourses should be restricted to one point only.

2. Use of all motorised boats should be prohibited.

3. Provision of an education centre for interpretive purposes to be located so as to relieve pressure on the most fragile areas.

4. Establishment of nature trails with observation blinds at appropriate points.

Proposals for management:

1. Use of a four year rotation in mowing the grassland area.

2. Maintenance of small units of agricultural land growing traditional crops.

3. Minimal attention to woodland; no "clearing up" of debris and leaf litter.

4. Limited use of chemicals.

4.4.3. A Conservation Plan for an Estate in Devon, England

A new estate to include housing and industry is being built in the Estover area of the City of Plymouth. The site

concerned is approximately 1,300 acres and now comprises woodland and agricultural land. A plan which attempts to retain, add to, and perpetuate landscape features important to the ecosystem has been presented to the City by the Devon Trust for Nature Conservation (DTNC)(Smith and Wheeler, 1970).

Wheeler (1969b:853) believes that the Estover development "clearly presents the possibility of including the conservation of the varied flora and fauna within the site and an opportunity to plan a unique experiment in co-existence between man and wildlife".

Principles of the plan:

1. Urban environmental quality can be enhanced through the integration of green space into the development during the planning stage.

2. It will be necessary to incorporate restrictions into the plan which will minimise sources of pollution in the new development in order to preserve communities within and beyond the Estover site.

3. There is a paramount need for the retention and provision of biological corridors to facilitate dispersal of animals throughout the area.

Strategies to maintain wildlife:

1. Retention of all hedges where possible together with at least a ten foot strip on either side to support under-mowed grassland.

2. All roads to be constructed with fifty foot margins planted so as to maximise diversity, using hardwood species with a conifer nurse crop.

3. Extension of the existing woodland into the heart of the development area by new plantings to give a continuous chain of wooded valleys separating the open spaces. It is recommended that hardwoods be planted in a matrix of conifers to provide good wildlife habitat.

4. Management practices such as mowing, cutting, or felling should be left to September when they will create the least disturbance to natural populations. Maximum floral diversity will thereby be encouraged and also smaller species will be favoured. It is suggested that the traditional practice of 'hedge steeping' be continued on a twelve to fifteen year rotation.

5. Creation of ponds should be attempted in selected areas.

6. Development of an arboretum and insect garden is recommended, on the site of a demolished house set in an overgrown garden.

7. Playing fields should form part of the biological corridor network and therefore care should be exercised to ensure that native vegetation is retained in such locations.

4.4.4. A New University Campus Developed to Enhance the Natural Landscape

The landscape architect Neil Porterfield has recently produced a plan for the new Parkside Campus at the University of Wisconsin. In approaching the project he applied certain principles which were discussed in the journal *Landscape Architecture* (1969, 60(1):31-33).

1. A detailed inventory together with site analyses of all natural and man-made features was conducted prior to the drawing up of the development plan.

2. A study of the ecological factors influencing the existing landscape was made.

3. Following upon identification of natural features of high aesthetic value (river valley, flood plain, and woodland), they were designated for preferential retention.

4. All planting and landscaping was based upon the principle of producing an area requiring only minimum maintenance. This is exemplified in the statement:

> It is our premise that a landscape planned in accordance with, and maintained by, practices simulating nature's

own processes will reduce maintenance. In contrast, horticultural treatment of institutional land holdings requires costly weekly mowings, frequent fertilizing, and pruning of introduced grasses and exotic species.

4.4.5. Roadside Verges as Wildlife Habitat

Wildlife inhabiting motorway verges in Britain has been discussed by Way (1970). Since the potential area of such land runs to 10,000 acres, studies are being conducted to determine the existing plant communities in roadside habitats and assist in the formulation of management plans.

It is essential that these areas be managed so as to develop stability since they are likely to become an increasingly important reservoir of wildlife. It should, however, be recalled that toxic concentrations of automobile pollutants can build up in such locations and this must be considered when attempting enhancement.

In the County of Kent, a co-operative arrangement between the County Council and the Department of Horticulture of London University has resulted in an experimental planting of new roadside cuttings to simulate natural cover. This project is being conducted in an area of high landscape value and thus re-establishment of typical vegetation was considered essential. The method required the cutting of turves (12" x 12" x 6") from adjacent areas of habitat and planting these in two lines 2'6" apart near the top of the bank. Turves of ling (*Calluna vulgaris*), bilberry (*Vaccinium myrtilis*), and bracken (*Pteridium aquilinum*) were used and eventually a

random block planting of the whole slope was accomplished. A review of the project showed that a 70 per cent establishment was achieved and the technique of planting two lines at the top of the bank successfully stabilised the topsoil so as to minimise erosion. Rapid colonisation of the bank by herbs and shrubs has occurred between the turves presumably as a result of the protection and the adequate supply of propagules in the immediate area.

4.4.6. Restoration of Derelict Common Land, England

Mitcham Common is a 400 acre open space in London which has been severely abused in recent decades through its use as a refuse tip. The London Borough of Merton has plans to re-instate a natural vegetation resembling that which originally existed (Boddington, 1971, personal communication). The area chosen for the pilot experiment is some twenty acres upon which with suitable contouring, addition of top soil, seeding, planting, and careful management, it is hoped to reproduce the picturesque quality of a sandy heath. The procedures employed are summarised:

1. An eighteen month survey was conducted to assess the various attributes of the entire area and to choose a pilot site.

2. Following re-contouring of the refuse tip and its clay overburden an acid (pH 5.5) topsoil will be applied.

3. Planting of saplings of native species such as oak, birch, and the introduced pine (*Pinus sylvestris*).Typical shrubs such as blackthorn (*Prunus spinosa*) and common buckthorn (*Rhamnus cathartica*) will also be encouraged to grow.

4. It is expected that natural colonisation by willow and elder will occur.

5. Two principal habitats are to be encouraged, namely grassland and woodland.

It is uncertain whether or not it will be possible to simulate the indigenous vegetation cover since the drainage conditions are not typical of those found on undisturbed sandy heath. In order to maintain the newly established cover all grassland will be mowed three times per year to simulate grazing.

4.4.7. Summary

From this assortment of projects it would seem that planned natural habitat is a valid element worthy of consideration in any land use plan. The expertise gained in these particular localities should be made known in order to encourage similar endeavours elsewhere. In the majority of cases, except the Wascana Waterfowl Park, the plans are still new or only partially implemented and it is impossible to assess their quality. Each one deserves a more detailed appraisal to evaluate the principles set, the techniques employed, and the results obtained.

These projects serve to emphasise the need for important natural sites to be identified prior to any development so that steps may be taken to safeguard their integrity by planning adjacent land uses accordingly. With respect to management practices it seems obvious that only minor changes

in technique can effect a considerable enhancement in the diversity of cover achieved and it can be recommended that more thought be given to making such changes in all maintenance activities concerned with public green space.

CHAPTER V

MANAGEMENT

Total land-use planning such as outlined in Chapter IV which includes provision of wildlife habitat is unlikely to prove rewarding unless an equally great effort is devoted to refining land management techniques (Duffey, 1967). In Chapter II it was pointed out that natural systems are dynamic, and change unidirectionally through time toward a higher degree of complexity unless counteracting forces intercede to prevent the successional modification of the environment. Management may therefore be viewed as a means whereby regression or progression of an ecosystem is altered to some predetermined plan. It is possible to manipulate physical factors such as drainage and water levels or modify the complexity of the system by the addition or removal of energy and materials; it is in fact a form of applied research (Nicholson, 1956).

To manage wildlife populations it is necessary to manage habitat since it is this which controls the ability of any species to thrive and reproduce effectively (Leopold, 1933; Graham, 1947; Dasmann, 1964; Giles, 1969; Teague, 1971).

5.1. Management Objectives

Management may be needed to protect and maintain an

existing habitat or it may be used to shape the development of a habitat in an area where none presently exists. Clearly, there is a great difference between these two objectives and this will determine the policies employed to achieve the desired end.

In all management activities one principle which should be adhered to is the maintenance of the highest degree of stability which is compatible with the system to be perpetuated. In the case of an early successional stage where stability will be minimal, the degree of management activity required will be most intense (Streeter, 1968). It has been accepted that diversity is associated with stability, therefore it should form the principal focus for all management practices concerned with habitat creation in urban areas.

5.2. Policies

Diversity can be enhanced by several means. Within any single community this can be achieved by encouraging the establishment of as large a variety of native species as possible. It can be further promoted by ensuring that the decomposer chain is maximised through the retention in situ of dead and dying organic materials (Manns, 1967). The structure and physiognomy of the vegetation should similarly be diversified since it is known to be a major determinant of animal density (Beecher, 1942; Colquhoun and Morley, 1943; Dowdy, 1947; Preston and Norris, 1947; MacArthur *et al.* 1962;

Beven, 1964; MacArthur, 1964; Hooper and Crawford, 1969; Recher, 1969).

In pursuit of variety, an alternative to the manipulation of a single community is the creation of adjacent ecosystems of varying age such that all phases of succession are represented in a region (Tischler, 1956; Odum, 1969). This approach would necessitate the rejuvenation of selected portions of the mature systems to ensure a continuity of heterogeneous units. This technique would provide a continuity through time in any one area, but at any specific location there would be a gradual development toward larger biomass, lower productivity, and greater stability. Given adequate linkage the inherent mobility and capacity for dispersal among animals and plants would ensure that these intentionally disturbed habitats were colonised.

In densely populated countries the landscape is either semi-natural or cultivated and the wildlife populations are adapted to these conditions. In order to retain these communities there may be a need to preserve the cultivation practices which have created them. Examples of such practices are the laying of hedges, coppicing of woodland, grazing of grassland, and cutting of reeds in fenland. As many varied land uses as possible should be encouraged so as to present a mosaic of habitats.

5.3. Techniques of Diversification

5.3.1. Topographic Modification

Landscape can be changed by remodelling the surface layers to create hills and depressions which will add greatly to the range of potential habitats available (Jellicoe, 1966; Weddle, 1967; Colvin, 1970; Fairbrother, 1970). Techniques for excavating ponds and lakes are well known but some are less appropriate than others. For example, the successful method known as 'pothole blasting' will be inapplicable to built up areas (Provost, 1948; Uhler, 1956; Chabreck, 1968; Hoffman, 1970). Earth moving equipment, however, can create shallow lakes and canals with little difficulty. In the vicinity of populated areas are numerous worked-out gravel and clay pits and there is evidence that these can yield to management and support waterfowl populations (Harrison, 1964; Olney, 1964; Glue, 1970). In larger ponds and reservoirs additional niches can be established by supplying rafts and logs to create "artificial islands" and also through the formation of bars and peninsulas (Sugden and Benson, 1970).

The use of earthen dams in areas of high water table should allow the creation of bog and marsh vegetation both of which are biologically rich (Bradley, 1951; Brumsted and Hewitt, 1952; Boyer and Devitt, 1961; Shomon et al. 1966; Niering, 1968; Bye, 1969; Smith, 1970a).

5.3.2. Increasing Species Diversity and Density

Variety is encouraged by the seeding and planting of

vegetation. In recent years techniques have also been devised for transplanting mature trees thus allowing an apparently mature system to be created in a short time. The subject of city trees and their culture has been considered by several authors (Knechtel, 1909; Min. H.L.G., 1958; Salter, 1960; Haddock, 1961; Marling, 1963; Civic Trust, 1966, 1967; Zion, 1968; Hebblethwaite, 1969).

In acquiring seed or saplings for urban planting these should be drawn where possible from local populations, in order to maximise their chances of establishment. All plantings should be mixed, with different species of both deciduous and evergreen form (van Dersal, 1940; Kubichek, 1941; van Emden, 1965; USDA, 1969). Furthermore, the presence of a variety of trees means that cover will be available earlier than if a single late-developing species were planted. This is very important since it influences songbird density and breeding success. The increase in vegetation diversity and stratification can bring about an automatic and complementary enhancement of animal variety provided that indigenous plants are used. Where it is thought desirable to encourage certain animals into the urban environment an attempt should be made to incorporate their preferred food plants into any vegetation plan. There is some literature on this subject and much more is likely to accumulate with the growing number of ecological studies in different communities (Collinge, 1936; Jones, 1940; Martin et al. 1951; Hartley, 1954, 1966; Owen,

1956; Olney, 1958, 1967, 1968; Davison and Hamor, 1960; Longnecker and Ellarson, 1960; Davison and Grizell, 1961; Parr, 1963; Dasmann, 1964; Davison, 1964; Kendeigh and West, 1965; Robel and Harper, 1965; Davis, 1967b; Pollard, 1967; Krull, 1970).

It is further possible to increase animal density by directly providing food materials but this can lead to severe oscillations in numbers if any discontinuity occurs in the food supply. Attempts to increase animal numbers are therefore accomplished by establishing food bearing plants in a suitable spatial arrangement (Nicholson, 1956).

Considering diversification from a temporal aspect, it will be necessary on a long term basis for periodic tree planting to ensure retention of uneven aged woodland containing a maximum number of niches. In order to achieve this there should be felling of small stands and creation of freshly turned soil to aid the establishment of locally distributed propagules. It is debatable whether climax dominants are capable of replenishing their numbers and it appears that the state of the soil surface may be a critical factor. Mellanby (1968) reports successful germination of oak seedlings in recently cultivated ground adjacent to mature woodland but within the woodland no sign of regeneration could be detected. He concluded that no satisfactory explanation was yet available for these observations. It would seem that intolerance of deep shade may be a factor limiting regeneration within the mature woodland.

There is considerable disparity of opinion among conservationists concerning the advisability of introducing species (Elton, 1958; Yapp, 1966; de Vos et al. 1967). It is feared that disruption of the ecosystem is inevitable when foreign species are allowed to enter a natural community. Howard (1965, 1967) states that our knowledge of the factors which regulate productivity and stability of ecosystems is still insufficient to warrant deliberate introductions of exotic species for whatever purpose. This question has been discussed recently by Lewin (1971) in connection with the Hawaiian Islands which appear to have been subjected to more introductions per unit area than any other part of the world. He notes that exotics pose a threat to native species particularly where they happen to be closely related, since hybridisation can occur and genetic integrity is thereby lost.

One of the reasons that mature systems possess stability is the intricate meshing of the interactions between species which serves to contain the size of any one population. These controls have evolved over millions of years and it is therefore not surprising to learn of the population explosions resulting from certain introductions (Elton, 1958).

In the United States it has been common practice among wildlife managers to import game species but the management effort required to maintain many of these animals has been very great (Dasmann, 1964; Gottschalk, 1967). Artificial breeding and subsequent release is another game

management technique which seems out of place when discussing natural populations in urban areas. If it is possible to establish reserve areas of viable size within the green space network such practices should be superfluous. It is unlikely in any case that artificial rearing can increase animal populations on a permanent basis since the primary limiting factor is suitable habitat (Boyd, 1957).

In North America, as previously mentioned, a considerable volume of literature has been assembled pertaining to game species but little attention has been directed to non-consumptive wildlife management (Giles, 1969; Hay, 1969; Hooper and Crawford, 1969, USDA, 1969).

As a general method the increase of the number of nesting sites has proved to be successful in enlarging animal populations (Brown, 1943; Stuewer, 1943; Terres, 1953; Craighead, 1961; Staude, 1966; Cohen, 1967; Busse, 1968; Davey, 1969; Kalmbach, 1969; Sawyer, 1969; Bishop and Barratt, 1970; Will, 1970). In city environments the deliberate provision of brickwork and masonry with various apertures can give shelter and breeding space to songbirds, owls and bats. From Schlangen in West Germany comes a report of two hundred new houses equipped with built-in nesting boxes that have attracted a variety of birds which used them successfully. Childrens' adventure playgrounds seem to offer excellent potential as nesting areas and this could be realised by the modification of some of the equipment

provided in such areas. Strawiński (1963) considers the most important limiting factor in the city environment is the paucity of nesting sites accessible to birds. Such a lack, it would appear, can be easily remedied at a minimum of expense and with a high degree of probable success.

5.4. Cropping and Control Techniques

Numerous methods are known for the control of vegetation and these range from manual through mechanical to chemical and biological. Each operates in a different manner, and depending on the objectives set in the management plan, some will be more appropriate than others.

There are many traditional cultivation practices which have produced the landscape we view today. Grazing has been effective in maintaining chalk grassland in southern England (Floyd, 1965; Wells, 1965). Pollarding of willow trees has increased the number of hollow and dying individuals thus creating many niches (Glue, 1970). Coppicing is a forestry practice which tends to maximise the biological richness of woodland (Rackham, 1967; Carlisle and Brown, 1967; Welch, 1968). Burning of moorland has been the major tool for the managers of grouse (*Lagopus lagopus*) in Britain and fire is also useful in preserving early successional phases (Picozzi, 1968; Lindsey C.C., 1970). However, in grassland burning to clear scrub is considered detrimental to the maintenance of floristic diversity in the turf (Lindsey C.C., 1970). In order to maintain wildlife populations in

commercially forested areas it is necessary to retain some mature vegetation within the felling zone, and the brushwood resulting from forestry operations can provide excellent cover if left in situ (Williamson, 1967).

In connection with urban wetland it is unfortunate that nutrient inputs are usually high and thus some removal of materials will be needed to regress the succession away from a mesic system. Repeated clearing of emergent vegetation and occasional dredging may be necessary and this should be done manually to avoid more than minimum damage (Clawson, 1969; Lindsey C. C., 1970; USDI, n.d.). A review of the problems attendant upon removal of riparian vegetation has been provided by Campbell (1970).

With the development of chemicals that act as growth inhibitors or accelerators a new tool was made available to conservationists and game managers. There has been a general acceptance that such chemicals are non-persistent and relatively harmless to wildlife provided they are used in accordance with recommendations (Allen, 1953; Way, 1969). In recent studies of game birds in France, however, there has been some evidence for mutagenic effects upon embryos, and this raises the question of the long term effects of such chemicals on ground-nesting birds (New Sci., 1970, 49:593).

Use of herbicides has been documented in relation to many non-agricultural land uses (Ibberson, 1951; Egler, 1952, 1954; Pound and Egler, 1953; Bramble and Burns, 1955;

Goodwin and Niering, 1959; Hopkins, 1961; Niering and Goodwin, 1963; Ward, 1964; Kenfield, 1966; Newton, 1967). In view of the current uncertainty as to the safety of herbicides and the known persistence of many available pesticides their application should be regarded as a last resort in managing urban wildlife habitat. In parks and gardens it is quite unnecessary to employ chemical controls since there is no requirement to grow perfect crops or flowers to fit some Madison Avenue image (Fowles, 1970). Unlike agricultural land, many urban gardens comprise a mosaic of small scale habitats, and because of the large number of niches normal biological controls are in force (Mellanby, 1967).

5.4.1. Control of Animal Populations

The problems involved in controlling sparrow, pigeon, and starling populations in urban areas have been reviewed by Thearle (1968). As he points out the most difficult aspect of the problem is the attitude of the public to any such culling. Neither cage trapping nor shooting were deemed permissible but use of narcotic baits held promise of being adequate and inexpensive if used against discrete populations (Ridpath *et al*. 1961; Murton, 1965). By conducting the treatment at dawn the probability of public reactions was minimised. The greatest success has been with sparrow populations; this was attributed to their attachment to specific colonies and the fact that only juvenile birds disperse to

new breeding sites (Summers-Smith, 1963).

Superabundance of any one species in an ecosystem can usually be attributed to ecological mismanagement and this can only be remedied by modifying the environmental conditions so as to place the undesirable population at a disadvantage (Lawrence, 1967). A reduction in carrying capacity is thus required to bring into play mechanisms such as competition and predation which will increase mortality and in some instances may reduce natality (Davis, 1953). It is debatable whether our knowledge of habitat requirements is sufficiently advanced to enable such an approach but it is worth exploring further. Traditional control methods attached great value to the concept of extermination but as has been pointed out by Cain (1966), if successful it merely creates a vacant niche which may then be colonised by yet another undesirable species.

5.5. Problems Associated with Use of Certain Management Techniques in Urban Areas

Not all the established methods will be transferable to the urban setting. Grazing for instance can be a most useful tool but in urban areas there is likely to be a problem with the number of dogs which could harass sheep (Reynolds and Sankey, 1967). Cattle might be used but hobbling would be required so that only chosen areas would be grazed. If allowed free access these animals cause damage to fragile vegetation and may reverse succession to an undesirable

degree (Dambach, 1944). In towns it will become increasingly unacceptable to use burning as a management technique due to the resultant air pollution and potential hazard to property.

5.5.1. Seasonal Use of Techniques

Where the primary objective of management is the maintenance of wildlife habitat, it is essential that care be exercised in the timing of all manipulation activity. An understanding of the ecology of each species is necessary in order that disturbance can be minimised. To maintain grassland, mowing should be carried out so as not to interfere with ground nesting birds. In addition, there should be monthly variation in cutting to avoid destroying the same plant species each year. Other activities such as thinning, felling, and pruning should also be timed to avoid the breeding season. Considerable difficulty may be experienced in deciding upon the 'best' time since many shrubs and trees furnish food and shelter all year round. However, most activity should be concentrated in the late autumn and winter months.

5.6. Problems Resulting from Human Use of Natural Habitat Areas

In addition to the presumed effects of environmental contamination on natural areas within the urban environment, there is in addition the direct influence of people, which may be conveniently discussed under two headings, damage and disturbance.

5.6.1. Damage

Trampling of vegetation is inevitable in any regularly used area and depending on the substrate, varying degrees of damage occur. On chalk grassland three levels can be observed - light trampling which has little effect upon the plants, medium trampling which abrades the plants to form a close cropped turf and reduces species diversity; and the third level where plants are completely killed and may be followed by soil erosion. Horse-riding has even more detrimental effects upon vegetation cover, particularly where soil moisture is high, as for example in woodland and along stream valleys. Cars often intrude upon the vegetation of natural areas with disastrous results (Perring, 1967a; Reynolds and Sankey, 1967; Lindsey C. C., 1970).

Collection of wildflowers and removal of whole plants is a great problem in the vicinity of populated centres. In southern England many plants have been extirpated from the countryside surrounding major settlements. The common primrose (*Primula vulgaris*) is such a plant whose occurrence is rare within a thirty mile radius of London (Lindsey C. C., 1970).

Accidental fires are frequent in heavily used recreational areas and these can have disastrous effects upon both flora and fauna. In England, bracken (*Pteridium aquilinum*) has acquired dominance on many acres of heathland due to its ability to withstand fires by virtue of its rhizomatous

habit (Watt, 1955).

5.6.2. Disturbance

The ability of many animal species to tolerate human disturbance is not well developed and this must be recognised as a limiting factor of considerable importance in urban areas. The type of activity which may be classified as disturbance includes deliberate nest destruction, collection of eggs and young animals, and harassment and injury to animals. It has been suggested for example that kestrels which in England have taken to living in suburban areas may be very vulnerable to nest predation in view of their popularity among falconers (Lond. Bird Rep., 1968, 32:85). More often destruction may be unintentional and stems from ignorance of the living system of which vegetation forms the foundation. Such occurrences as the breaking down of lakeside vegetation by fishermen in order to secure a suitable fishing spot and the beating down of undergrowth by inept golfers are two typical problems.

Shooting is illegal in most urban areas but air guns are popular with children and may be a serious problem in localised districts where isolated wildlife populations could conceivably be endangered (Lond. Nat., 1963, 42:101; 1967, 46:139). During the breeding season freedom from repeated disturbance is essential if young are to be successfully reared. It is for this reason that sanctuary areas are indispensable in the urban environment. For some animals however,

the mere presence of people can drive them away from one small but essential part of their territory thus forcing them to abandon the area entirely. In southern England bats have been disturbed due to people visiting caves which have served as roosts for centuries (Lond. Nat., 1968, 47:43).

Introduction of a variety of materials to natural areas seems an inevitable effect of human usage. The distribution of all forms of litter and refuse can have marked effects upon plant growth and animal mortality. Materials which are not decomposable distort plant growth even killing individual specimens and discarded containers can act as lethal traps for small animals and invertebrates (Harper and Morris, 1965). Another result of the influx of large numbers of people to a natural area is the increased probability for introduction and removal of spores, fruits, and larvae on clothing and footwear; these may be transferred between widely separated locations via the motor vehicle. A report of studies conducted on a heavily used piece of downland in Sussex shows that noticeable inputs of nutrients to soil occur as a result of human use and this fertilising effect alters both species composition and luxuriance of the vegetation (Lindsey C. C., 1970).

It is obvious that urban natural areas will be unduly influenced by their location and the need is for techniques to relieve some of the pressures of use. If stable, natural communities are desired, it will be necessary to manage people

in addition to the other components of the ecosystem.

5.7. Distribution of People in Recreational Areas

In order that the management of people can be most effective, it will be necessary to improve our understanding of the way people use open space. If detrimental effects upon wildlife are to be minimised the conflict zones between human and wildlife activity must be defined and the habitat manipulated so as to minimise the confrontation. For example, Forman (1968) points out that the places most favoured by recreationists are the habitat boundaries such as waterside, forest edge, and hillsides which are also those most useful to wildlife.

There is an observed tendency for people to stay relatively close to the main points of access to any natural area. Highways are the principal focus for recreationists and in metropolitan parks most people stay within one hundred feet of their parked cars (Satterthwaite and Marcou, 1969). It is not easy to predict whether such limited penetration will similarly apply to natural areas situated in residential districts. The presence of a high percentage of children in the populace who will be playing in a "known" rather than a "strange" environment is likely to result in a more extensive use of the area and in consequence the disturbance of wildlife will be greater.

5.8. "People Management"

5.8.1. Controlling Access

There is considerable evidence for the benefits of establishing certain parts of any area as a sanctuary where wildlife can remain relatively undisturbed (Lond. Nat., 1965, 44:158; Grant, 1967; Lond. Bird Rep., 1967, 31:65; 1968, 32:68). In London's Kensington Gardens for instance, the largest increase in bird numbers and species type has been reported from the Long Water Sanctuary which occupies a mere two acres within the total area of 275 acres (Lond. Bird Rep., 1970, 34:55).

The manner of controlling access may be varied according to the local situation, but careful site planning can provide a built-in zoning by making some areas more inaccessible than others. Water can exercise a strong inhibition to entry, thus islands automatically become sanctuaries provided no boating is allowed. In woodland it is feasible to fence off key areas leaving paths between to allow people visual but not physical access. To protect fallow deer (Dama dama) in Epping Forest on the outskirts of London, enclosures have been established with "deer leaps" to allow the adults freedom to come and go as they please while at the same time restricting the exit of young animals. Fawns born within the enclosure are unable to leave this area until they are at least one year old and this has considerably reduced the death toll on adjacent highways (Lond. Nat., 1963; 42:101; Chapman, 1969).

An effective and inexpensive barrier to human access is provided by thorny shrubs. Such species as bramble (Rubus sp.), blackthorn, gorse (Ulex sp.), and holly (Ilex sp). will inhibit human entry while providing excellent cover.

Prevention of the entry of cars can be achieved through use of various devices. Adequate car parking space in a carefully chosen location should always be the prime objective. In addition, the blocking of footpaths and trails by earthen ramps, fences and gates, or water-filled canals, can control the distribution of this source of noxious pollutants and noise.

Increasingly it has been realised that restrictive controls alone can never provide adequate protection in the face of intensive human use and the popularity of nature trails has provided one positive means of controlling the areas of use. Trails may be guided or self-guided but either way they reduce the tendency to wander randomly and thus substantially reduce the disturbance to wildlife. Careful planning of the trail layout is essential and should have the objective of directing people away from the areas of greatest importance to breeding animals.

5.8.2. Education

In the final analysis the most rewarding form of people management will be educational programs designed to create positive attitudes toward natural resource conservation.

The primary aim of any program should be the encouragement of an awareness of the human role in the biosphere. Particular stress should be laid upon the responsibility of each individual to press for the establishment of a stable, contained system which optimises energy and material usage, and satisfies all levels of human need.

Education should be regarded as an indispensable tool which can proximately contribute to the protection of urban wildlife habitat by ensuring that it is not used beyond its ecological carrying capacity, and ultimately hold the key to the survival of the human species.

An effort to make wildlife more accessible to the public while at the same time providing adequate protection from disturbance is likely to prove the most challenging problem for the urban resource manager. Accessibility of wild animals can be greatly enhanced by providing nature trails with observation blinds equipped with suitable optical aids at strategic locations (Wildfowl Trust, 1956). In the city there are many opportunities for the installation of observation posts in such locations as parks, golf courses gravel pits and reservoirs, refuse dumps, sewage farms and churchyards.

Involvement of local people in the management activities of natural areas is one way of encouraging an enlightened interest and is particularly applicable where children are concerned. Rawley and Peucker (1970) recorded that

children use parks to a much greater extent than do other age groups. When reclamation of waste tips was first attempted in Britain, youthful vandalism was the greatest deterrent to success of the planting programs. Realising this, the administrators undertook an information and education campaign in the schools and involved children in the replanting scheme which significantly improved the chances of successful establishment of cover.

To integrate the educational programs, interpretive centres should be established in the principal green spaces to provide information and expert help in the enjoyment and use of these areas.

5.9. Management of Urban Green Spaces

There is little sign of an understanding among city administrators of ecological principles pertaining to habitat management. Indications of an enlightened attitude to planned development of natural landscapes are also sadly lacking. Typical abuse of open space is its use as a repository for all forms of litter and waste and many biologically rich locations have drowned under a welter of garbage. In London there are numerous examples of ponds on common land being "reclaimed" by filling with rubbish (Lond. Nat., 1962, 41:25; 1967, 46:24; Mitcham Common Survey, 1967).

Abuse of vegetation also takes the form of destruction of old timber, pruning without appreciation for the growth form of the tree concerned, and the placing of notices and

brackets on and around trees which damage the bark and allow pathogens to enter the tissues. Timing of management operations is rarely considerate of wildlife requirements and much damage results from such ignorance (Lond. Nat., 1961, 40:22; 1962, 41:66; Lond. Bird Rep., 1963, 26:79-80).

Too often the principal concerns of park managers are pest control, reduction in property damage, and provision of flamboyant and temporary displays of exotic species, all of which involve high energy input and large expenditures of funds and man hours. The result is a highly unstable system.

Roadside verges suffer from heavy-handed management which neither enhances their appearance nor their usefulness as wildlife habitat. Repeated blanket spraying eliminates colourful flowers producing a mono-culture sward (Egler, 1954; Perring, 1967b; Way, 1967).

5.9.1. Proposed Guidelines for Urban Open Space Managers

Objectives: To encourage multiple areas supporting viable populations of wild species within the urban matrix.

Policies and Guidelines:

1. Planned development of any kind within the city should consider the provision of wild areas.

2. Retention and creation of biological corridors should be given priority in all development plans to maintain the viability of all open spaces as wildlife habitat.

3. Attention should be paid to increasing diversity wherever feasible by such means as:
   a. interspersion of different land uses
   b. planting of mixed species to create multi-stratified vegetation cover
   c. retention of decaying vegetation and animal matter in situ since they are enriching components of the ecosystem

4. The importance of linear habitat should be recognised and hedges, verges, utility rights-of-way, stream banks, and walls should be provided or retained. Efforts should be directed to the management of such habitat to maximise its biological potential and enhance its function as a corridor.

5. In all management plans the need to rejuvenate some habitats on a periodic basis should be accomplished by small scale disturbance over limited areas, e.g. the clearance of glades in woodland, the thinning of scrub, removal of emergent vegetation around small ponds, and the cutting of grassland on a three year rotation.

6. Seasonal operations should be organised to cause minimum disturbance to wildlife activities, i.e. concentration of activity should be in late autumn and early spring. Where possible manual rather than mechanised techniques should be used.

7. The use of chemicals should be abandoned in favour of other forms of vegetation manipulation. Enclosures should be erected to encourage regeneration of plants rather than rely upon the use of fertilisers.

8. Sanctuary zones for wildlife should be established which can then function as reservoirs for the remainder of the green space network.

9. The high biological value and protective function of wetlands, such as bogs and marshes, should be accepted. These areas should be protected from would-be refuse tippers and from drainage schemes or other forms of detrimental activity.

10. Acceptable modes of people management should be developed to create a general awareness of the ecosystem and its functioning. Damage should be minimised by restricting use to a level below the ecological carrying capacity.

11. The rotation technique should be adopted as a major protective tool in all areas subjected to intensive human use. For example, different portions of a parkland should be periodically fenced to exclude people and allow recovery of vegetation. Alternative walking trails should be provided so as to maintain each one within its ecological carrying capacity by periodic closure.

CHAPTER VI

CONCLUSIONS

When first conceived this study presumed that little attention had been paid to the subject of urban wildlife ecology and this has been confirmed. It is true that specific topics within the general subject area have been investigated as for example lichens in cities, suburban songbird ecology and control of urban pest species but little evidence has emerged of any effort devoted to a synthesis of the available material. In North America until very recently there has been undue emphasis upon consumptive wildlife management which goes some way to explaining the basic problem encountered during the study namely, a dearth of published facts. Much of the more valuable information must still reside with the conservationists, many of whom are non-professionals and therefore not exposed to pressure for publication of their findings. This leads to a most unfortunate situation where opinion is widely available (USDI, 1969) but solid information is largely unobtainable.

In the light of the information acquired the questions posed in the first chapter may now be reviewed. The first of these considered the existence of urban areas which had associated with them viable natural communities. The description

of London and the analysis of factors contributing to its role as a wildlife area provide evidence that natural communities can be maintained in such places. Further investigations in other countries might be expected to reveal several other locations where a similar natural element of the cityscape persists.

The second question on the subject of values is essentially unanswered by the study since this aspect of urban ecology is less amenable to investigation by a geographer. In many of the sources consulted various psychological values are attributed to the presence of nature in the city but little data or references are cited. It would seem that this is an interesting facet which should be taken up by both sociologists and psychologists whose information could be useful to planners and perhaps to the medical profession. Involved in this question of aesthetic values are the additional economic implications of the influence that greenery and songbirds have on people's location decisions. Some themes for further research which may be suggested are:

1. Is there any evidence for positive effects upon health and mental well-being as a result of having regular contact with natural phenomena, living organisms and natural processes?

2. Does the presence of wildlife in close proximity to houses create an awareness in people which is then reflected in the value they place upon such aesthetic resources? Does it in any way make them more aware of their role in the ecosystem?

3. Is it possible that awareness of nature in the vicinity of the home will alert people to more distant conservation issues, e.g. retention of wilderness areas?

4. What factors influence a person's perception of wildlife?

5. What practical value with respect to pollution control and reduction can vegetation play in the built environment? What are the medical implications of this?

6. How much of the monetary value of property stems from the form of the surroundings? Does the presence of a mature and diverse residential landscape raise the desirability of a neighbourhood in any quantifiable way?

Turning to the third question which concerned the possession of special characteristics it is apparent that some groups of plants and animals are more prominent in urban areas than others. Omnivores are prevalent as too are nocturnal mammals and those capable of flight, in fact any organism that shows adaptable behaviour can potentially thrive in the built environment. These observations lead to the conclusion that creatures of the city will inevitably be those normally associated with the early successional stage of a sere where a premium is placed upon features such as adaptability, high productivity and rapid turnover, unless some provision is made for biological diversity in the environment. The possibility for highly specialised animals to establish themselves is exceedingly low because of the inherent perturbations of the urban system.

Leading on from this is the consideration of the limiting factors exercised upon urban wildlife populations. In common with rural populations the greatest and most powerful force is that of man's activities which lead to habitat destruction. Furthermore, the increasing amount of

environmental contamination bids fair to extirpate many species which were formerly considered abundant, for instance the common frog and the partridge (Perdix perdix) from both the city and the countryside in Britain.

With respect to both these limiting factors there is but one answer and that lies with the practitioners of habitat management.

A fundamental problem with urban natural habitat areas is the wide chasm which exists between those who possess the essential information which would allow management of habitat to further diversify wildlife and those whose task it is to manage these areas.

Ecologists must therefore recognise the necessity to turn some attention to the numerous and challenging problems of the built environment in order that habitat management may move from its present state of being speculative exercise to one where controlled experimentation becomes the norm.

Not only the ecologist but those in the wildlife management field should consider which facets of the present body of information may be applied in the urban setting. There would seem to be a need to assemble this knowledge and present it for the use of those who will be confronted with the task of managing the predicted enlargement in natural habitat area in tomorrow's city.

Some of the suggested areas for applied ecological research include:

1. Controlled experiments in habitat creation.

2. Investigations of the minimum size of different habitats in addition to the problem of maintaining the area in the desired phase.

3. Investigations of common urban species, to better understand their population dynamics and thus provide the necessary information by which their numbers could be controlled in the event that this becomes necessary. Other aspects of urban wildlife characteristics requiring attention are migration, competition and adaptation.

4. Investigations of the carrying capacity of different types of habitat in the city.

5. Derivation of techniques whereby this capacity might be raised.

6. A search for techniques to maintain human use within the ecological carrying capacity.

7. Consideration should be given to the disparity between the perception of the natural landscape by the layman and the professional ecologist. This is important since it is the layman who essentially controls the decisions which protect or desecrate natural areas.

8. Derivation of an easily assessed "Habitat Index" for use by non-specialists in determining the value of potential habitat.

For planners the most important message to be heard is the absolute necessity for retention of natural habitat whenever and wherever it is feasible to include it as an integral part of development. The argument for bulldozing a site clean and then preparing a beautiful landscaping plan to add a green finish to the development is highly suspect. It must be eminently more reasonable to retain the natural beauty of a site and set the buildings within this framework so as to perpetuate a high quality landscape than it is to scrape away all vestiges of mature biological form and later

recreate them in a matter of days. If McHarg (1969) and his followers are correct it should prove more economical to pursue a rational approach to landscape development, through the use of ecological analysis as the basis for all land use planning.

It behooves planners to study further such schemes as those now in progress at Columbia, Maryland and Estover in Devon to ascertain whether indeed it is more or less costly and what kind of problems emerge from the application of this "planned nature" concept.

A difficulty to be expected in these planned communities where communal open space is retained concerns the management of these areas. Unless special forms of administrative agency are established there is considerable danger that such communal areas may become sources of strife and potential danger to the human residents in the locale. Planners must therefore take upon themselves the added responsibility for provision of some form of after-care advice. Perhaps, each development in which significant green space is included should be provided with a detailed five-year management plan to ensure that the original objectives are met.

A problem which will exercise those responsible for the management of city habitats is that of controlling the people who use these areas. Vandalism and ignorance may well represent the greatest threat to any efforts at urban

wildlife enhancement. Restrictive measures alone will not provide a cure and positive steps must be taken through the imaginative use of natural barriers and judicious location of wildlife areas with respect to conflicting land uses. Educational devices designed to create awareness and a desire to comprehend more fully the complexity of nature will provide the other principal tool for protection of habitat.

It was noted earlier that one key to success in this respect may be the involvement of the public in the management of natural areas. A great deal of unused talent and knowledge goes to waste at the present time in North America and this source could be tapped to ensure the well-being of city wildlife populations, as indeed is done in Great Britain where the amateur naturalists are in the forefront of the conservation movement.

It is therefore clear that the subject of urban ecology is one demanding an inter-disciplinary approach if we are to improve the factual basis of decision-making in this particular facet of resource management. No single discipline can seek the answers that are essential if we are to ensure that urban wildlife enhancement does not degenerate to the point where it becomes indistinguishable from unintentional pest propagation.

GLOSSARY

ADAPTABILITY	-	The ability of an organism to respond to changes in its environment so as to continue living and reproducing; no genetic change is involved.
CARRYING CAPACITY	-	The maximum level to which the resources of a habitat can be deployed without inducing instability.
CITY	-	An area where artefacts dominate the landscape and people are concentrated = Urban area = Built area = Urban environment.
COMMENSAL	-	The relationship of two species which interact such that one receives benefit while the other is unaffected.
COMMUNITY	-	All the organisms living in one area.
COPPICING	-	Cutting of trees, down to stools, every fifteen years (e.g. Hazel or Chestnut).
CULTIVATED AREA	-	Land upon which flora and fauna are controlled to further human ends.
ECOLOGY	-	The study of relationships between organisms and their environment.
ECOTONE	-	A border zone between habitats (e.g. woodland edge, shoreline and riverbank).
EDGE EFFECT	-	The tendency for increased variety and density at community junctions.
EDGE SPECIES	-	Organisms residing in "edge" habitat generally require more than one type of habitat in order to live and successfully reproduce.
ENVIRONMENT	-	Everything outside the individual organism, (used here in a loose way to mean physical surroundings).

FERAL	-	Animals which were once domesticated or possessed domesticated ancestors, and now live without support of a human owner.
FLORA	-	The sum of the plant species occupying an area at a given point in time.
GARDEN	-	The open space associated with a house - includes lawns, flowerbeds, shrubbery, and vegetable patch = Backyard.
GREEN SPACE	-	Open space which has a vegetation cover = "green lung".
GREEN BELT	-	A planning device whereby undeveloped land surrounding an urban area is protected from unplanned development.
HABITAT	-	The place where an organism (or a community of organisms) lives. It is commonly defined with respect to the type of soil, topography and vegetation which occupy the area.
INDIGENOUS	-	Original, not subjected to man's influence = Primitive = Native.
LANDSCAPE	-	That zone at the interface of the lithosphere-hydrosphere and the atmosphere perceived by man.
MANAGEMENT	-	Manipulation of natural materials and processes to a predetermined plan.
NATURAL AREA	-	An area where biotic and physical processes dominate over man's influence. Thus a landscape (or part thereof) with its natural vegetation cover and associated fauna.
OPEN SPACE	-	Land which is predominantly undeveloped = Unbuilt land.
PARKLAND	-	A landscape comprised of standard trees set in grassland.
POLLARDING	-	The practice of lopping trees in order to produce a close-rounded head of young branches.

POLLUTION	-	Disruption of energy fluxes and material cycles by human activities.
PROPAGULES	-	Any part of a plant capable of forming a new organism = Fruits = Seeds = Spore.
SEMI-NATURAL AREA	-	Flora and fauna are native or introduced in the long distant past, but the vegetation has been modified by human activity away from the potential vegetation for the site.
URBAN ENVIRONMENT	-	Cities and suburbs - wherever buildings, streets, gardens and other land uses have replaced the natural landscape. A contained, highly interrelated system of natural and man-made elements in various mixes.
URBANISATION	-	The process in which rural depopulation is accompanied by a concentration of the populace in major urban centres.
VEGETATION	-	Natural and semi-natural complexes of plant communities - the total plant cover of an area.
WILD	-	Non-domesticated, although not necessarily original or primitive.
WILDLIFE	-	All non-domesticated organisms.
WILDLIFE CORRIDORS	-	Linear cover providing concealment, between open spaces or in built-up areas allowing dispersal and migration.
WILD LANDSCAPE	-	Natural area.

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APPENDIX A

The questionnaire despatched to ecologists in Europe and North America in July, 1970, together with the covering letter.

DEPARTMENT OF GEOGRAPHY

THE UNIVERSITY OF ALBERTA
EDMONTON 7, CANADA

Res. 1/L/670

Dear

I am attempting to bring together knowledge on the subject of urban ecology, in the belief that we have for too long ignored the possibility of enhancing and diversifying our towns and cities by skilful management of the wildlife resource. In future it may become an accepted part of suburban and city development, that natural areas capable of supporting viable animal communities, be incorporated. Thus the planners and landscape architects will need to have access to the experience gained by wildlife managers, naturalists and ecologists.

The benefits of such schemes would be appreciable both in terms of aesthetics and education of the urban populace. No doubt there would also be problems but I hope that these may be revealed as the survey proceeds thus allowing suitable evasive action to be taken.

Attached is a questionnaire which should indicate the scope of the subject as I perceive it. While it is realised that not every question will be applicable, you are requested to provide any information you feel is pertinent to the survey.

Your co-operation will be greatly appreciated.

Yours truly,

Penelope Bonnett

PAB/dck
Encl.

Res. 2/s/770

Can you provide information on any of the following points:-

1. a) Cities which support notable wildlife populations.
   b) Cities with old-established parks and recreation areas which have diverse animal populations in addition to such species as pigeons and sparrows.
   c) Researchers or agencies which have pursued studies of urban flora and fauna.
   d) Areas within or adjacent to towns, which have been specifically managed to encourage wildlife.
   e) Suburban forestry schemes.

2. a) Management practices used in Nature Reserves which may be applicable to the urban environment.
   b) Minimum area requirements for particular wildlife habitat-types.
   c) Ecological and/or physiological differences between urban and rural flora and fauna.
   d) Ecological studies conducted in man-created or highly disturbed habitats.
   e) Detailed, long term studies of derelict land reclamation, where viable wildlife communities have resulted.
   f) Species for which adequate information exists to allow creation of suitable habitat.

3. a) Have you been consulted by town planners, developers, engineers, landscape architects or others, for advice on habitat creation? Did this result in a published report? If so please give title and publishing agency. Was the advice implemented?
   b) To your knowledge, have any 'New Towns' included wildlife habitat in their early plans, so as to conserve existing natural communities?
   c) What would the desirable objectives be for any plan to encourage wildlife into the city and the guidelines necessary for its implementation?
   d) What disadvantages can be foreseen if a wildlife enhancement policy was adopted in urban areas?
   e) Do you feel that present knowledge is adequate to consider such a policy?

APPENDIX B

Agencies Visited	Location	Personnel Interviewed
Conservation Foundation	Washington D.C.	Anne Satterthwaite
Izaak Walton League of America	"	Don B. Cullimore
National Recreation Park and Association	"	Diana Dunn
USDI, Bureau of Sport Fisheries and Wildlife	"	Jack Berryman Keith G. Hay Dan Saults Dan Styles
North American Wildlife and Natural Resources Conference	Chicago, 1970	Delegates
Countryside Commission	London, England	Use of libraries
Greater London Council (Parks Department)	"	Superintendent
Nature Conservancy	"	Use of libraries
Royal Society for the Protection of Birds	Sandy, Bedford-shire, England	John Taunton Michael Everett

<u>Correspondents</u>

Dr. P. Davies	Dept. of Zoology U. of Nottingham	Nottingham, England
Dr. F. W. Stearns	Dept. of Botany U. of Wisconsin	Milwaukee, Wis., U.S.A.
K. G. Hay	USDI BSFW. (Now of Amer. Petroleum Institute)	
Dr. D. Pimlott	Dept. of Zoology U. of Toronto	Toronto, Ontario, Canada

APPENDIX C

A list of cities which are known to have significant wildlife areas within their environs.

Location	Natural Area	Size
Amsterdam, The Netherlands	Woodland - Amsterdamse Bos (includes lake, marshes, grassland and woods)	2,200 acres
Oostelijk Vlevoland, The Netherlands	Lakes Wooded areas (Bird reserves of grassland, marsh and woodland)	11,000 acres 7,500 acres
Dublin, Ireland	Phoenix Park (parkland with fallow deer herd)	1,760 acres
	North Bull Island (Waterfowl and water reserve of saltmarsh, sand dunes and mudflats)	
Frankfurt, W. Germany	Enkheimer Ried (wetland bird sanctuary)	
Hamburg, W. Germany	Fischbeker Heide, (woodland nature reserve)	
Ann Arbor, Michigan U.S.A.	Island Park (waterfowl area)	
Chicago, Ill. U.S.A.	Cook County Forest Preserve (woodland)	40,000 acres
Milwaukee, Wis. U.S.A.	Juneau Park (Waterfowl lake)	
New York, U.S.A. (Long Island)	Jamaica Bay Refuge (Tidal marsh system)	11,840 acres
Philadelphia, Pa. U.S.A.	Tinicum Wildlife Refuge (Marsh associated with tidal estuary)	205 acres

APPENDIX C - continued

Location	Natural Area	Size
Rochester, Ma. U.S.A.	Silver Lake (Waterfowl area)	20 acres
Washington D.C., U.S.A.	Rock Creek Park (wooded river valley)	1,754 acres
Craigavon, Northern Ireland	Planned retention of important biological sites and creation of wildlife habitat.	
Smoke Rise, N.J., U.S.A.	Planned suburban development with retained wildlife habitat.	3,500 acres

APPENDIX D

Maps showing major green spaces in London.

LONDON
Scale
0
1
2
4 MILES
WATFORD
RICKMANSWORTH
BARNET
ENFIELD
EDGWARE
HARROW
UXBRIDGE
SOUTHALL
EALING
ACTON
WILLESDEN
HAMPSTEAD
HIGHGATE
TOTTENHAM
WALTHAMSTOW
STRATFORD
ILFORD
ROMFORD
BARKING
HOUNSLOW
RICHMOND
KINGSTON
WIMBLEDON
CROYDON
BROMLEY
DARTFORD
EPSOM
WEYBRIDGE
STAINES
SUTTON
THAMES